TRIPLEN HARMONICS STUDY AT GAS DISTRICT COOLING, UNIVERSITI TEKNOLOGI PETRONAS (GDC, UTP)

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Triplen Harmonics Study at Gas District Cooling, University Teknologi PETRONAS (GDC, UTP)

by

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PROJECT DISSERTATION

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Nazirah Binti Mat Rashid)

ABSTRACT

The voltage and current waveform in AC power circuits are expected to be sinusoidal with constant amplitude and frequency. However under certain extent, all power plant components posses the undesirable property of introducing distortion into the AC power circuit causing the voltage and current waveforms to deviate from their otherwise intended sinusoidal form. Therefore, the voltage and current waveform are decomposed to the frequency that are integer multiples of fundamental frequency that called harmonics. The triplen harmonics currents are the harmonics currents that are always multiplied by 3. The objective of this studies is to investigate the existence of the triplen harmonics at Gas District Cooling, Universiti Teknologi PETRONAS (GDC,UTP).

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INTRODUCTION

1.1 Background of the Study

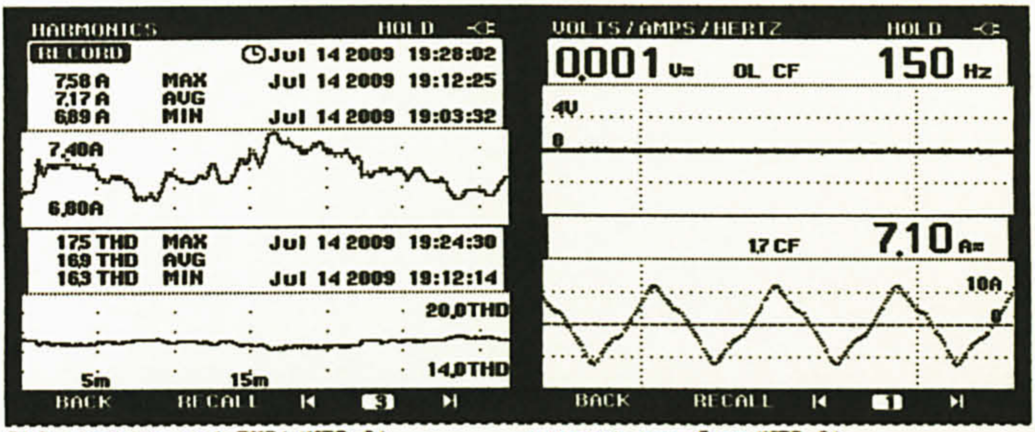
In Universiti Teknologi PETRONAS (UTP), electrical power is supplied from Gas District Cooling (GDC) plant. It has two gas turbine generator (GTG) units. The highest recorded maximum demand is 7.9MW with each generator capable of delivering 4.2 MW. Under certain circumstances UTP will require Tenaga Nasional Berhad (TNB) supply to cater for the load or as a back up. Below is the information about GDC plant:

Year Of Construction	:	2000
Year Of Commercial Operation	:	2001
Owner	:	Universiti Teknologi Petronas (UTP)
Operator	:	Makhostia Sdn. Bhd.
Product	:	Electricity and chilled water for UTP campus
Plant Capacity	:	8.4 MW- Electricity; 4000 RT- Chilled water

1.2 Problem Statement

During the measurement on GTG's neutral earthing resistor (NER) when two generators are parallel operation with TNB supply, it was observed triplen harmonic current exist as in figure 1.

Mode 4 (NER GTG-A)



RMS current and THDi (NER A) current waveform (NER A)

Figure 1: NER A Harmonic Measurement

Based on observation to the pattern of the current waveform in figure 1, it is no longer sinusoidal, therefore we can said it is being distorted and there is harmonic distortion exist.

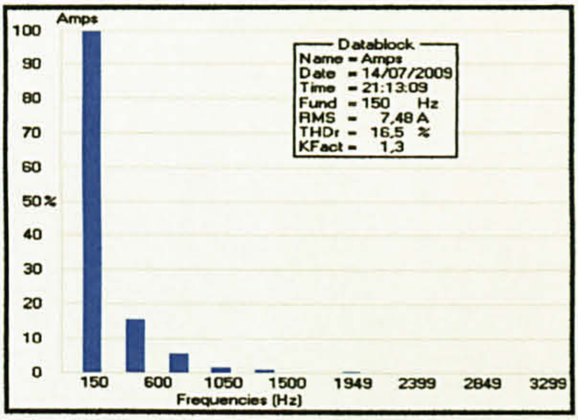


Figure 2: NER A Harmonic graph

Table 1: Harmonics current at NER A

n	Freq (Hz)	Current (% A)	Current (A)
1	50	0.00	0
3	150	100	7.48
5	250	0.00	0
7	350	0.00	0
9	450	15.7	1.17
11	550	0.00	0
13	650	0.00	0
15	750	5.40	0.40

Based on the figure 2 and table 1 above, its shows that the harmonics exist here is triplen harmonics currents.

1.3 Objectives and Scope of The Study

1.3.1 Objectives

The objectives of this study are:

1) To ascertain the source of triplen harmonics currents
2) To verify that the triplen harmonics currents is produced by the generator and not come from TNB or load.
3) To find out the reason of NER currents is higher when parallel with TNB

1.3.2 Scope of the Study

The study of triplen harmonics currents includes the research, surveys, data collection, calculation, analysis, solution's proposal and technical presentation. The study begins with the research on triplen harmonics and data measurement at the GDC plant. Then data analysis is made to meet the objectives of the study.

CHAPTER 2

LITERATURE REVIEWS

2.1 Harmonics

Harmonics are currents and voltages that are integer multiples of the fundamental frequency. Harmonic currents provide power that cannot be used and also takes up electrical system capacity. Large quantities of harmonics can lead to malfunctioning of the system that results in downtime and increase in operating costs.

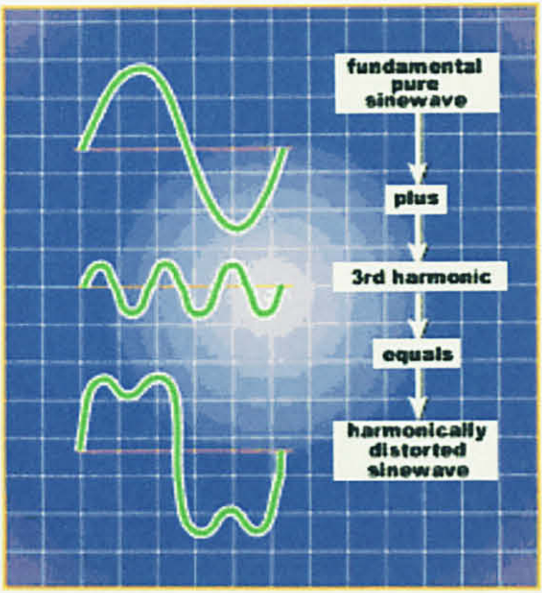


Figure 3: sinewave of harmonics distortion

Harmonic study analysis is very important task for the consultant and engineers in every industrial project. It is because of the widely and heavily used of thyristor controlled equipment in most industrial plant. A lot of harmonics studies have been done in the industry today to install a new power supply line.

Equipments producing harmonics represents a significant portion of the total connected load of modern industrial systems. The effect of harmonics can be noticeable in many ways such as voltage and current distortion, low voltage notching, communication systems interference and high voltages and currents in case of resonance. Harmonics may cause relay disoperation, PLC interference, equipment failures, capacitor fuse interruptions and high overall system losses.

Harmonic study analysis must be conducted in the engineering design stage of all industrial systems that include harmonic producing equipment, alongside load flow and short circuit studies. The interaction between load flow and harmonic study should lead to the best system configuration design, optimal operating conditions and proper size and location of power factor correction capacitors. When medium voltage capacitor banks are considered, it is also important to conduct transient analysis study to assess the possibility of switching problems.

Harmonics studies are performed to determine the harmonic distortion levels and filtering the requirements within a facility. Field measurement and computer simulation are used to determine the harmonics as well the effectiveness of the filter specification. An evaluation of the harmonics are depends on the IEEE standard 519.

The potential for harmonics distortion problems is dependent on two important factors, the level of harmonic generation that can be associated with the loads in the plant and the system frequency response characteristics. Both factors will determine the harmonics problems exist at a particular bus. It is also possible for harmonic problems to occur at buses remote from the harmonic source if local resonances exist. If capacitors are applied at any locations that have large adjustable-speed drives, the potential for resonance problems must be considered carefully.

The harmonic currents generated by the load or more accurately converted by the load from fundamental to harmonic current have to flow around the circuit via the source impedance and all other parallel paths[1]. As a result, harmonic voltages appear across the supply impedance and are present throughout the installation. Source impedances are very low so the harmonic voltage distortion resulting from a harmonic current is also low and often hardly above the network background. This can be misleading because it gives the impression that there is not likely to be a harmonic problem when in fact large harmonic currents are present. It is rather similar to trying to find a circulating earth current with a voltmeter. Whenever harmonics are suspected, or when trying to verify their absence, the current must be measured.

There are several common problem caused by harmonics: -

1) Problems caused by harmonic currents:
   - overloading of neutrals
   - overheating of transformers
   - nuisance tripping of circuit breakers
   - over-stressing of power factor correction capacitors
   - skin effect
2) Problems caused by harmonic voltages:
   - voltage distortion
   - induction motors
   - zero-crossing noise
3) Problems caused when harmonic currents reach the supply

2.1.1 Harmonics Sources

The increasing in use of power electronic devices for the control of power apparatus and system has been the reason for the greater concern about waveform distortion in recent time.

The examples of the harmonics source are:

1) Single phase loads
   a. Switched mode power supplies (SMPS)
   b. Electronic fluorescent lighting ballasts
   c. Small uninterruptible power supplies (UPS) units

2) Three phase loads
   a. Variable speed drives
   b. Large UPS units

Same things happen in the power plant where the harmonics distortion is on increase. The tendency of electronics based plant components and rotating machinery to inject harmonic distortion into the AC network is aggravated by the geometric imbalance presented in the network. Magnetic non-linearities acting under saturating conditions and electric arc furnaces may also play and important part in aggravating the problem.

2.1.2 Harmonics produces by the generator

Slot Harmonics

The tooth or slot harmonics is produced by regular variations in reluctance and flux along the stator's surface. The use of distributed winding introduces to the regular variations that produce harmonic components.

The slot harmonics occur at frequency that been set up by the spacing adjacent shot and are given by

$$V_{(slot)} = (2MPS/P) \pm 1$$

$V_{(slot)}$ = number of the harmonics component

S = number of slot on stator

M = an integer

P = number of poles on the machines [3]

Triplen harmonics current in the generator

The synchronous generators have high impedance, Xd, that usually govern much of the fault current. This will create unexpecting consequences that the harmonic voltage distortion increase intolerable levels when the generator is attempting to supply adjustable-speed drive loads. Another is the voltage waveform produced by a synchronous machine is not perfect, therefore its contain third-harmonics in the certain design and result in high third-harmonic currents flowing in the generators and also in the utility system.

The third harmonic of any periodic wave is the frequency of that wave multiplied by three. On a well designed system that balances the load between the three phases, the electric current on the neutral conductor from these three phases almost completely cancel each other out, leaving very little current traveling through the neutral conductor.

However, when triplen harmonics (all odd multiples of the third harmonic) are present in the electrical system, they do not cancel each other out on the neutral conductor. Their phases match up, therefore they add together and producing a large current. These current heats up the neutral conductor and the transformer that is feeding the system, and can damage the installation.

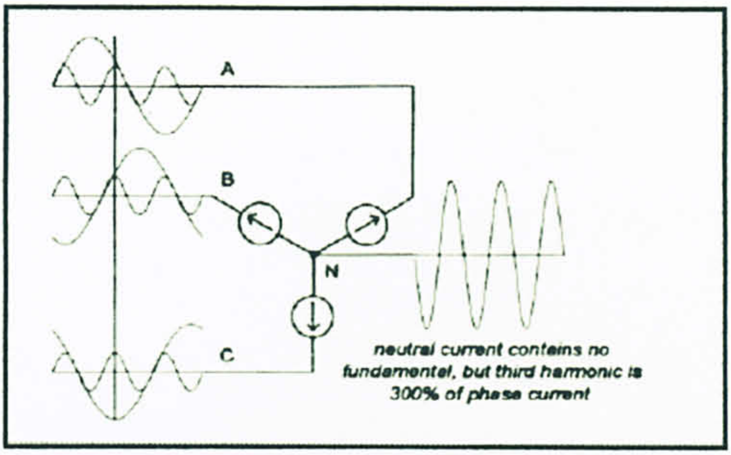


Figure 4: The summation of third harmonic current in neutral conductor

Harmonics from generators come from inverters and some synchronous machine. It is surprised to found that there is high current circulating on neutral when the generator is parallel to the utility system. Inverters operating in parallel are less likely to form an island if they are acting as current sources and hast destabilizing signal that is constantly trying to shift the frequency reference out of band [8].

2.2 Earthing

In electrical systems, the neutral earthing is used to:

- Limit the potential of current-carrying conductors with respect to the general mass of earth.
- Provide a current return path for unbalance current and earth faults in order to allow protective devices to operate.

Within the generation, distribution, transmission and industrial networks, the neutral earthing is typically used on the secondary winding transformer and on the windings of generators. Usually, electrical systems are earthed via their star point or neutral. There are three types of neutral earthing;

- Neutral solidly earthed
- Neutral earthed via impedance (resistors, inductors, resonant devices)
- Isolated

Where there is more than one generator operating in parallel, the subject of neutral/earthing circulating currents can be dealt with following arrangements;

a) A neutral earthing transformer connected between the phases and earth. This enables the neutral of the installations to be permanently earthed, with the generators connected to the busbars as three-wire machines.
b) Star-point switching to connect the star point of only one generator to earth during parallel operation.
c) A suitable reactor in the neutral connection of each generator which will attenuate higher frequency currents without offering significant impedance at mains frequency [1].

2.3 Neutral Earthing Resistor (NER)

Neutral earthing resistors (NER) are used in Power distribution stations for neutral earthing for generator or transformer winding. If the generator(s) operates in Island or Stand-by mode then each generator shall be separately earthed via an earthing resistor.

NER are designed to limit the current flow to earth under fault conditions. This NER limited fault current is low enough to prevent damage to the generating, distribution and other associated equipment yet high enough to operate fault clearing relays. The rating of the NER is chosen so that the fault current is limited to that necessary to operate the protection relays within the required time. In continuous process applications, where continuity of supply is critical, high resistance neutral earthing can be used to reduce the risk of service interruption caused by earth fault. For maximum benefit, it is necessary to detect, locate and clear earth faults as quickly as possible.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identify

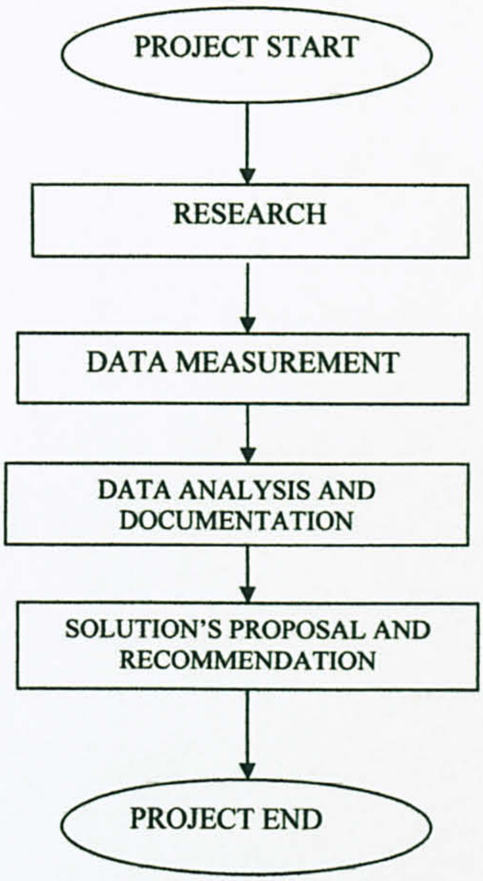


Figure 5: Flow chart of the project

3.2 Project Activities

Table 2: Project Activities

NO	PROJECT ACTIVITIES	KEY MILESTONE
1	Study on harmonics	Understand all about harmonics distortion that effect power quality (what is harmonics, the affect, the source of harmonics, data collection method, harmonic's calculation, interpretation on harmonics)
2	Data acquasition	Harmonics data at GDC and Seri Iskandar TNB substation.
3	Data Analysis	Excellent interpretation of the data
4	Solution's Proposal and recommendation	Solution proposal on the analysis data and recommend the mitigation methods to mitigate harmonics

3.3 Tools and Equipments Required

3.3.1 Hardware

- Power Quality Analyzer, Fluke 43B

The "Power Quality Analyzer, Fluke 43B" is used to measure the harmonics current.

3.3.2 Software

- Fluke View
- Microsoft Exel

CHAPTER 4

RESULT AND DISCUSSION

4.1 GDC Mode of Operation

GDC operates in four different mode of operation.

1. **GDC mode 1 operation** – one GTG operates in island operation
2. **GDC mode 2 operation** – two GTG's operate together in island operation.
3. **GDC mode 3 operation** – one GTG operate in parallel with TNB in parallel operation.
4. **GDC mode 4 operation** – two GTG operate together in parallel with TNB in parallel operation.

The operation of GTG's in GDC is depends on the load demand.

1. Load demand is lower than 4.2 MW, one GTG will operates in GDC mode 1 operation.
2. Normal load demand in UTP is 7.9 MW, so two GTG's will operate together in GDC mode 2 operation.
3. Load demand is more than 4.2 MW but less than 7.9 MW, GTG will operate in GDC mode 3 operation.
4. Load demand in need is more than 7.9 MW or in certain circumstances of event, GTG's will operate in parallel with TNB in mode 4 operation. TNB is used as a back up or for more load demand.

4.2 Triplen Harmonics Currents Measurements

4.2.1 GDC Mode 1 operation

The NER current measurement is done on 7 May 2010 at GTG B. Figure 6 show the NER current value and figure 7 show the harmonics spectrum.

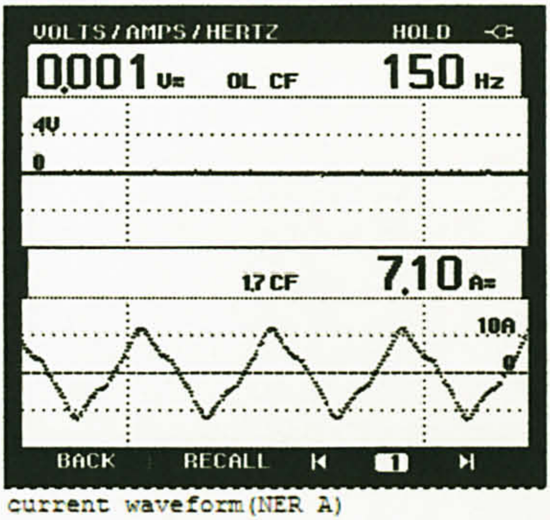


Figure 6: NER GTG B current waveform

The graph in figure 6 shows that the waveform is being distorted.

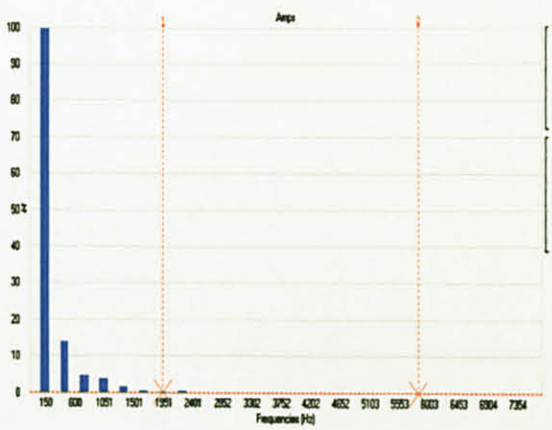


Figure 7: NER GTG B Harmonic spectrum

when there is no connection with GDC. Therefore, we can said that the harmonics current is not exist at TNB NER when there is no connection with GDC.

4.2.3 GDC Mode 2 Operation

The NER current measurement is done on 12 April 2010 at both GTG A and GTG B. Figure 10 and 11 below shows the NER current value and harmonics spectrum of GTG A.

NER A of Mode 2

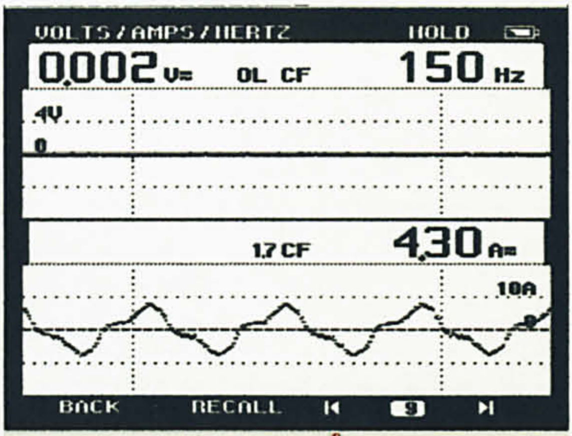


Figure 9: NER GTG A current waveform

The graph in figure 9 shows that the waveform is being distorted.

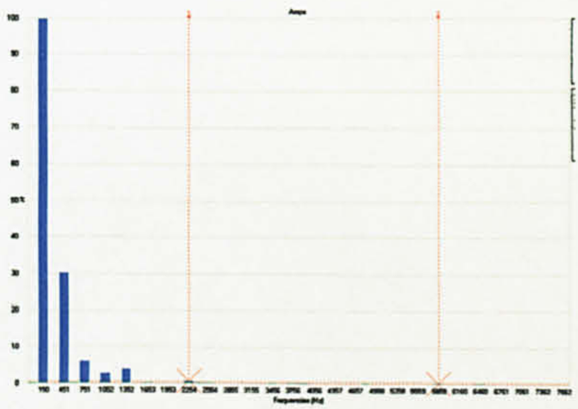


Figure 10: NER GTG A Harmonic spectrum

Table 4: NER GTG A Harmonic Current

ORDER	FREQ(HZ)	% AMPS	AMPS
1	50	0.00	0
3	150	100.00	3.17
5	250	0.00	0
7	350	0.00	0
9	450	30.2	0.95
11	550	0.00	0
13	650	0.00	0
15	750	6.00	0.19

The third harmonics order is 100% with the current value of 3.17A. The first harmonics order with the fundamental frequency of 50Hz is zero current.

NER B of Mode 2

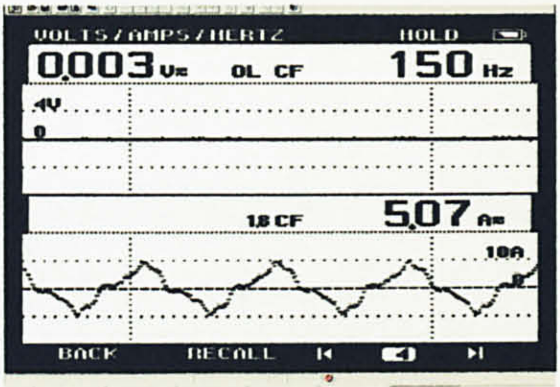


Figure 11: NER GTG B current waveform

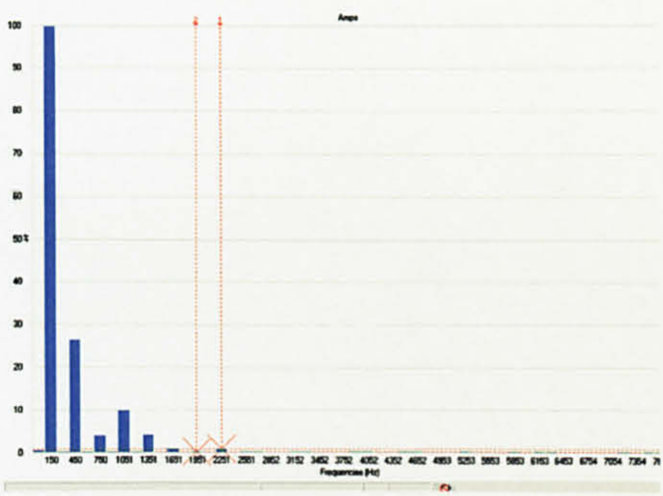


Figure 12: NER GTG B Harmonic spectrum

Table 5: NER GTG B Harmonic Current

ORDER	FREQ(HZ)	% AMPS	AMPS
1	50	0.00	0
3	150	100.00	5
5	250	0.00	0
7	350	0.00	0
9	450	26.4	1.32
11	550	0.00	0
13	650	0.00	0
15	750	3.9	0.195

This measurement verified that the triplen harmonics currents are also exist in the GDC mode 2 operations.

4.2.4 GDC Mode 3 Operation

The harmonics measurement have been made at NER of GTG B on 25 march 2010 during parallel operation with TNB

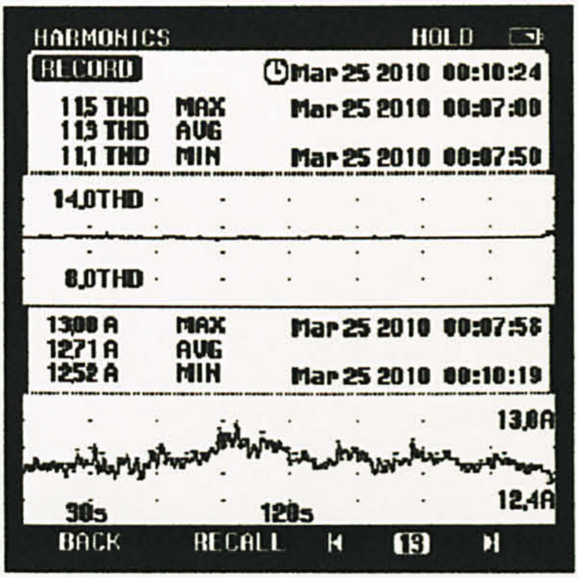


Figure 13: NER GTG B current and harmonics waveform

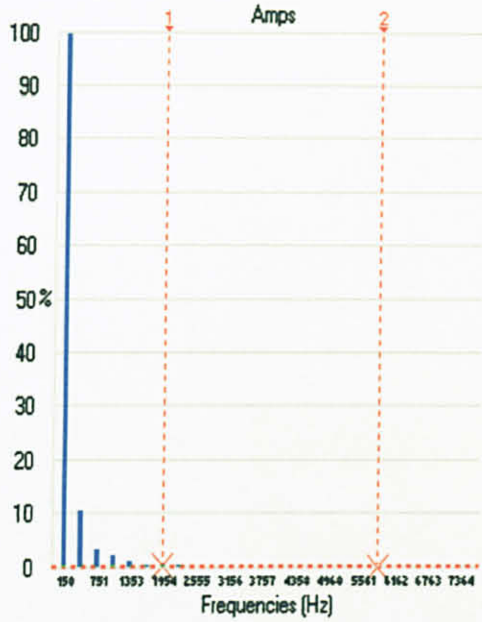


Figure 14: NER GTG B Harmonic Spectrum

Table 6: NER GTG B Harmonic Current

ORDER	FREQ(HZ)	% AMPS	AMP
1	50	0.00	0.00
3	150	100.00	12.55
5	250	0.00	0.00
7	350	0.00	0.00
9	450	10.6	1.33
11	550	0.00	0.00
13	650	0.00	0.00
15	750	3.40	0.43

The harmonics current at third order is 12.55A and it's the highest in compare to the order three modes. Its show that when GTG in parallel operation, it tends to produce more triplen harmonics currents.

4.2.5 GDC Mode 3 Operation - TNB NER Measurement

The harmonics measurement has been made at NER of TNB substation Seri Iskandar on 24 March 2010 during parallel operation with GTG B.

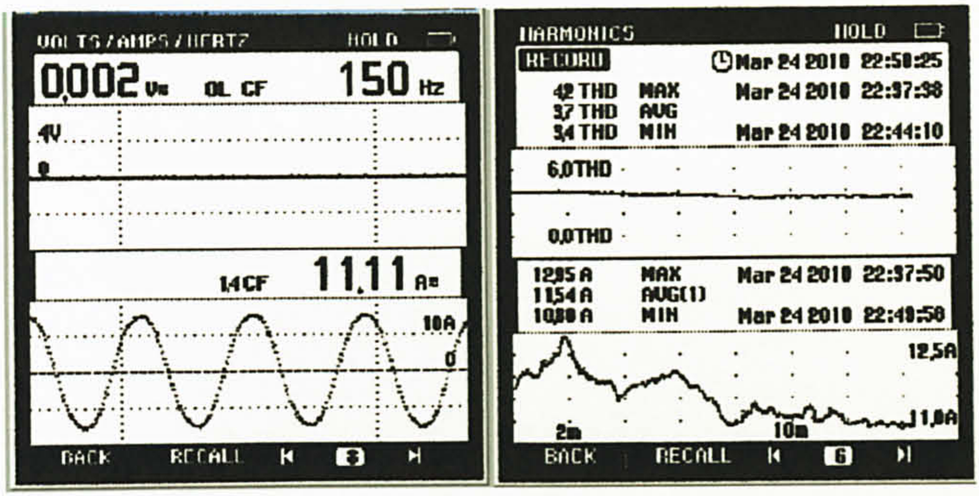


Figure 15: NER TNB current and harmonics waveform

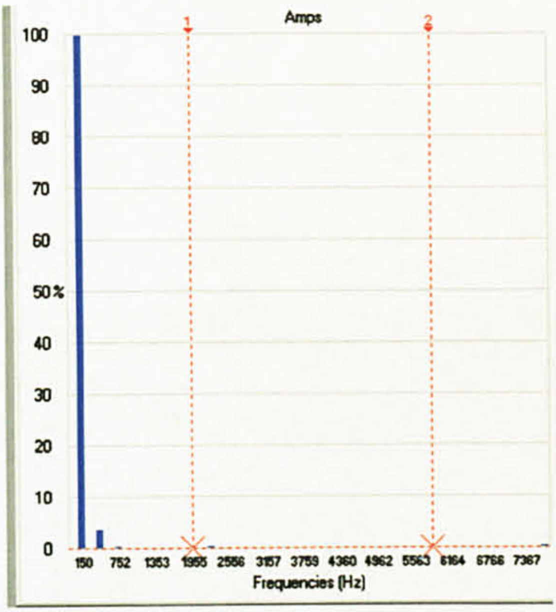


Figure 16: NER TNB Harmonic Spectrum

Table 7: NER TNB Harmonic Current

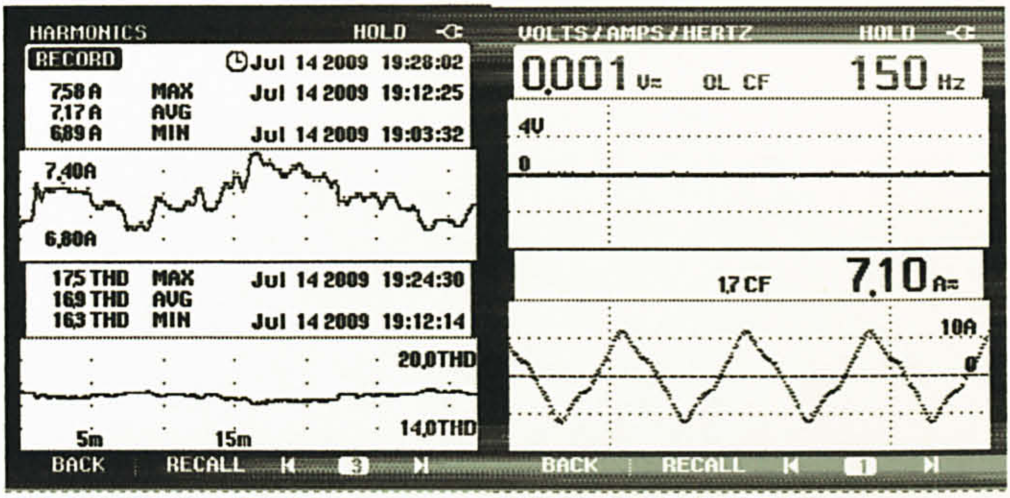
ORDER	FREQ(HZ)	% AMPS	AMPS
1	50	0.00	0
3	150	100.00	11.23
5	250	0.00	0
7	350	0.00	0
9	450	3.6	0.40

The graph shows that there is harmonics current also exist at NER TNB. The third harmonics current is 100% with the current value of 11.23A, while the other orders are zeroes. The 9th order is 3.6% with current value of 0.40A. This shows that the triplen harmonics is also exist at the TNB substation when parallel operation with GDC.

4.2.6 GDC Mode 4 Operation

The harmonics measurements have been made at NER of both GTG A and GTG B on 14 July 2009 when GTG's operate in parallel with TNB in mode 4.

Mode 4 (NER GTG-A)



RMS current and THDi(NER A)   current waveform(NER A)

Figure 17: NER GTG A current and harmonics waveform

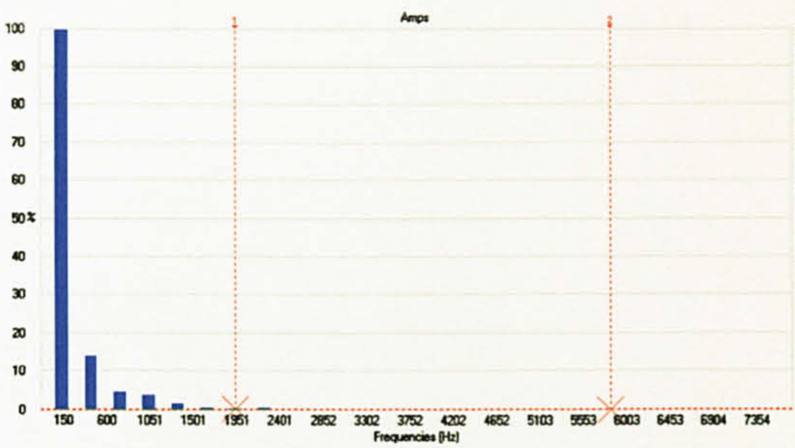


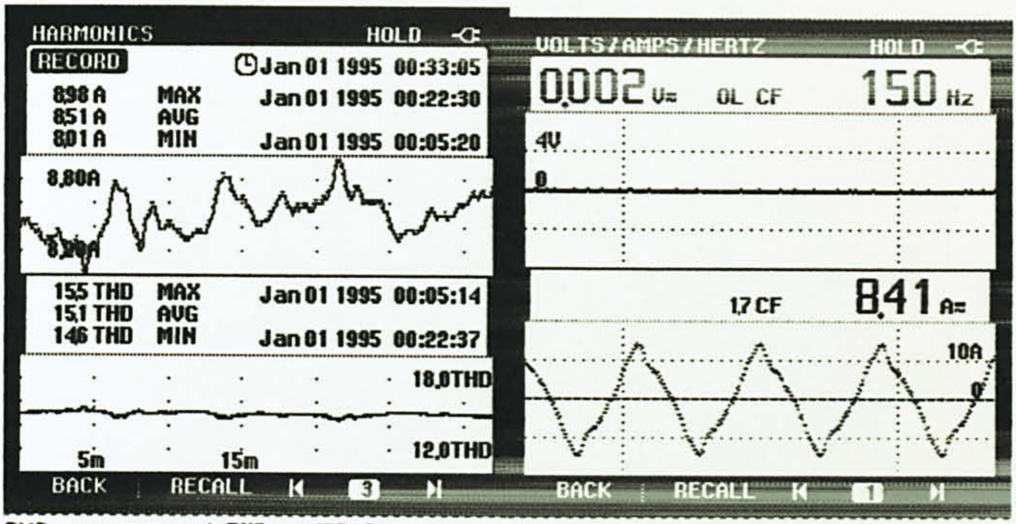
Figure 18: NER GTG A Harmonic Spectrum

Table 8: NER GTG A Harmonic Current

ORDER	FREQ(HZ)	% AMPS	AMPS
1	50	0.00	0
3	150	100.00	7.48
5	250	0.00	0
7	350	0.00	0
9	450	15.70	1.17
11	550	0.00	0
13	650	0.00	0
15	750	5.40	0.40

The third order harmonics current is 100% with the current value of 7.28A.

Mode 4 (NER GTG-B)



RMS current and THDi (NER B) Current Waveform (NER B)

Figure 19: NER GTG B current and harmonics waveform

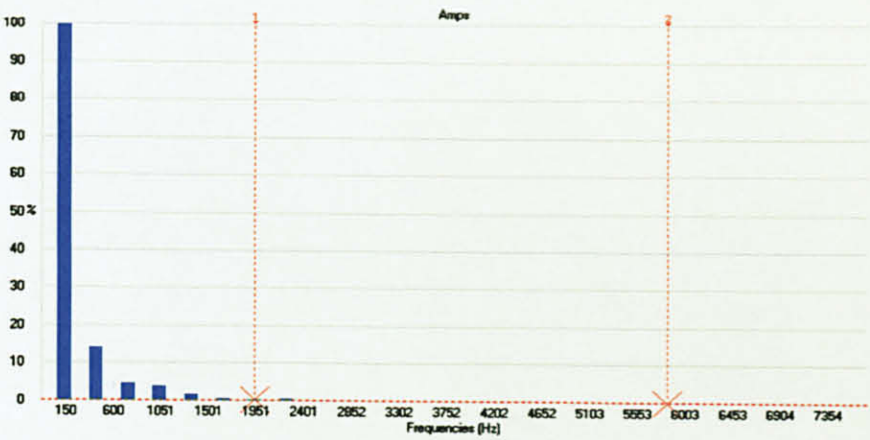


Figure 20: NER GTG B Harmonic Spectrum

Table 9: NER GTG B Harmonic Current

ORDER	FREQ(HZ)	% AMPS	AMPS
1	50	0.00	0
3	150	100.00	8.54
5	250	0.00	0
7	350	0.00	0
9	450	14.10	1.20
11	550	0.00	0
13	650	0.00	0
15	750	4.60	0.39

The third order harmonics current is 100% with the current value of 8.54A.

This measurement verified that there is triplen harmonics current exist in the mode 4 operations.

From the graphs and table shows in this section, we can see that all GDC modes of operations are having triplen harmonics current. Mode 3 produce the higher triplen harmonics current as individual, while mode 4 produce most highest triplen harmonics current because of the summation of NER currents of the generators that operate at the time. The harmonics that exist is verified as triplen harmonics current according to the pattern of harmonics order that having currents values. From the measurement on TNB NER, it is show that the triplen harmonics currents that exist at TNB are coming into the TNB NER. the harmonics current it not being produced by the TNB as there is no harmonics exist when there is no connection between TNB and GDC. However when there is parallel operation with GDC, TNB NER having triplen harmonics currents. From these data, it is verified that the triplen harmonics currents are not being produced by the TNB. The triplen harmonics currents flow from GDC to TNB.

4.3 GTG's Produced Triplen Harmonics Currents

Usually the harmonics are being produced by the load and flow to the source, however in this case, the harmonics are produced by generators. The harmonics measurements have been done by Group Technology Solution (GTS) at Universiti Teknologi Petronas (UTP) and it is found there is harmonics current exist. Therefore it is verified that the harmonics currents do exist at the load side. However these harmonics currents cannot flow to the GDC as the transformer in use is delta-star transformer. In zero sequence network system, the delta connection does not allowed the harmonics currents flow through to the GDC side.

Therefore the triplen harmonics currents that exist in the GTG's NER are not coming from the load. As the triplen harmonics currents also have been prove do not coming from the TNB, thus these harmonics currents that exist in GTG's NER can be said is generated by GTG's itself. The next section will prove that the triplen harmonics currents are produced by GTG's and how the triplen harmonics currents flow in the system.

4.4 How the Triplen Harmonics Flow

In order for triplen harmonics current to circulate, there must be a closed zero sequence path. The closed path can be any device which is grounded as shown in figure 21.

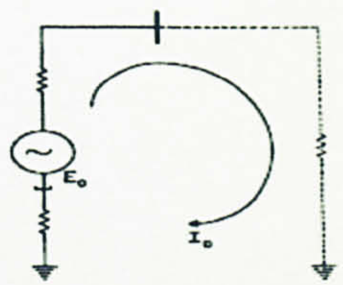


Figure 21: Circulation of the triplen harmonics current

As we know, all cable has impedance that consists of resistor, inductor and capacitance. This cable capacitance provides a zero sequence path to the triplen harmonics currents to circulate back to the generators as shown in figure 22.

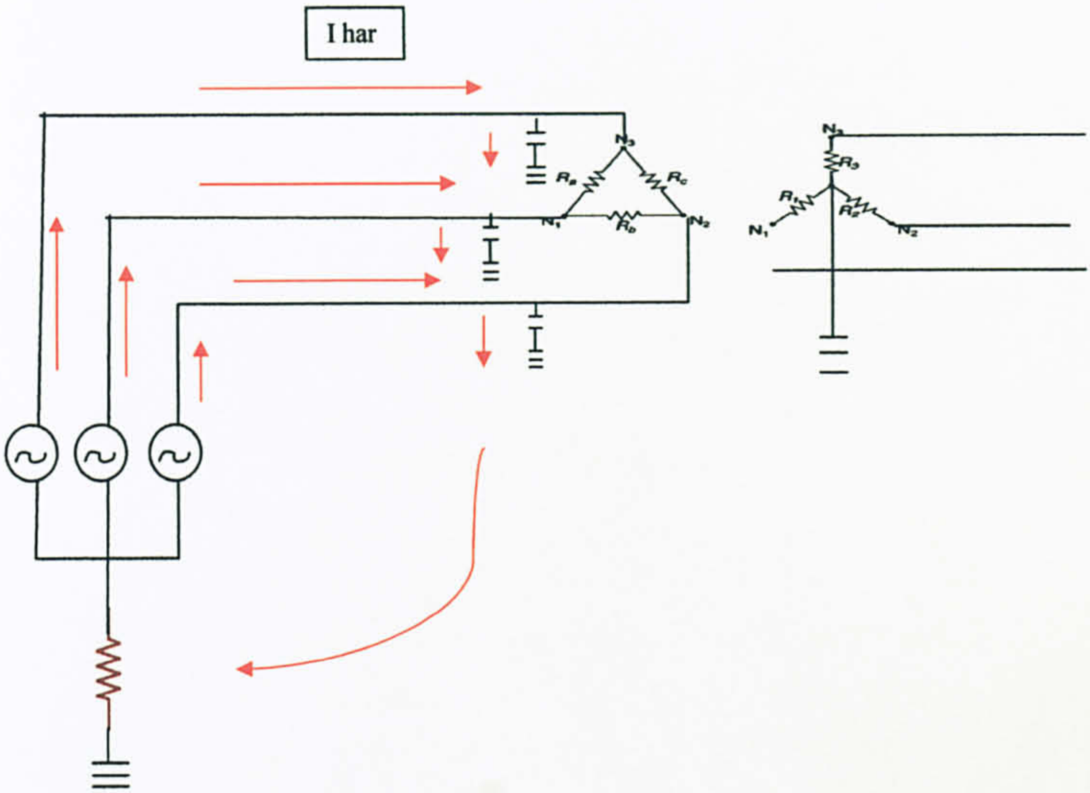


Figure 22: The triplen harmonics current flows through the cable capacitance to circulate back into the generator

Impedance is the cable ratio of electric field strength to the magnetic field strength of waves propagating in the cable and is measured in Ohm's unit. Ohm's Law states that the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them.

The mathematical equation that describes this relationship is:

$$I = \frac{V}{R}$$

As stated in Ohm's law, When voltage (E) is applied to a pair of terminals and a current (I) is measured in the circuit, the impedance (Zo) can be calcuted by this equation;

$$Z = E / I$$

$$Z = R + j(X_L \pm Xc)$$

Where capacitance is calculated by this formula;

$$Zc = 1/j\omega C$$

$$\text{While } \omega = 2\pi f$$

Therefore Zc will equal to :

$$Zc = 1/j(2\pi f)\, C$$

From above equation, the varying frequency will affect the value of the capacitance. When the frequency is low, the capacitance will be large and when the frequency is large, the capacitance will be small. Back to Ohm's law, the current are proportional to the impedance (in this case, the impedance is the cable capacitance that provide the path for the triplen harmonics currents to flow through). When capacitance is large, the current will be small while when capacitance is low, the current will be large.

In this case of study, the harmonics is the propagation of wave that is multiple of the fundamental frequency. Therefore, the frequency is always changing and increasing. The triplen harmonics current is the third harmonics order that always multiple 3 times. Therefore at third order, the frequency is 150Hz, when its multiple by 3, then the frequency will become 450 Hz at 9^{th} order. The increase in frequency will then decrease the cable capacitance that will give more currents to flow through.

4.5 Flows of the Triplen harmonics Currents

This section will show how the triplen harmonics current flows and circulate back in each mode of operation. Then its will verify that the triplen harmonics current are produced by the generators.

4.5.1 Island Operation

This section will show how the triplen harmonics currents flow and circulate back into GTG's NER in island operation.

The triplen harmonics currents flow from the generator through the cable to the load side. The delta transformer does not provide a path for the triplen harmonics currents to flows through to the load side, but also do not have any path for the triplen harmonics currents to flows to the earth. Thus the triplen harmonics currents find the most able path to flow through. As we discussed earlier, for the cable, it has cable impedance that consist of capacitance that provide a path to the earth. Thus the triplen harmonics currents then flow through this cable capacitance to the earth as shown in figure 23 and 24. In normal condition, the current cannot flow through this capacitance because of the value of the capacitance is higher and the currents that can flow through will be very small enough to be detected. The cable impedance is design to have enough impedance to avoid losses in transmission. However the design in based on the fundamental frequency, 50Hz. When the frequency deviates and become multiple integers than the fundamental, the impedance value will decrease and will allow more current to flow through it. The more frequency increase, the larger volume of currents can flow through cable capacitance. Therefore these triplen harmonics currents are able to flow to the ground and circulate back to the generators.

GDC Mode 1 operation

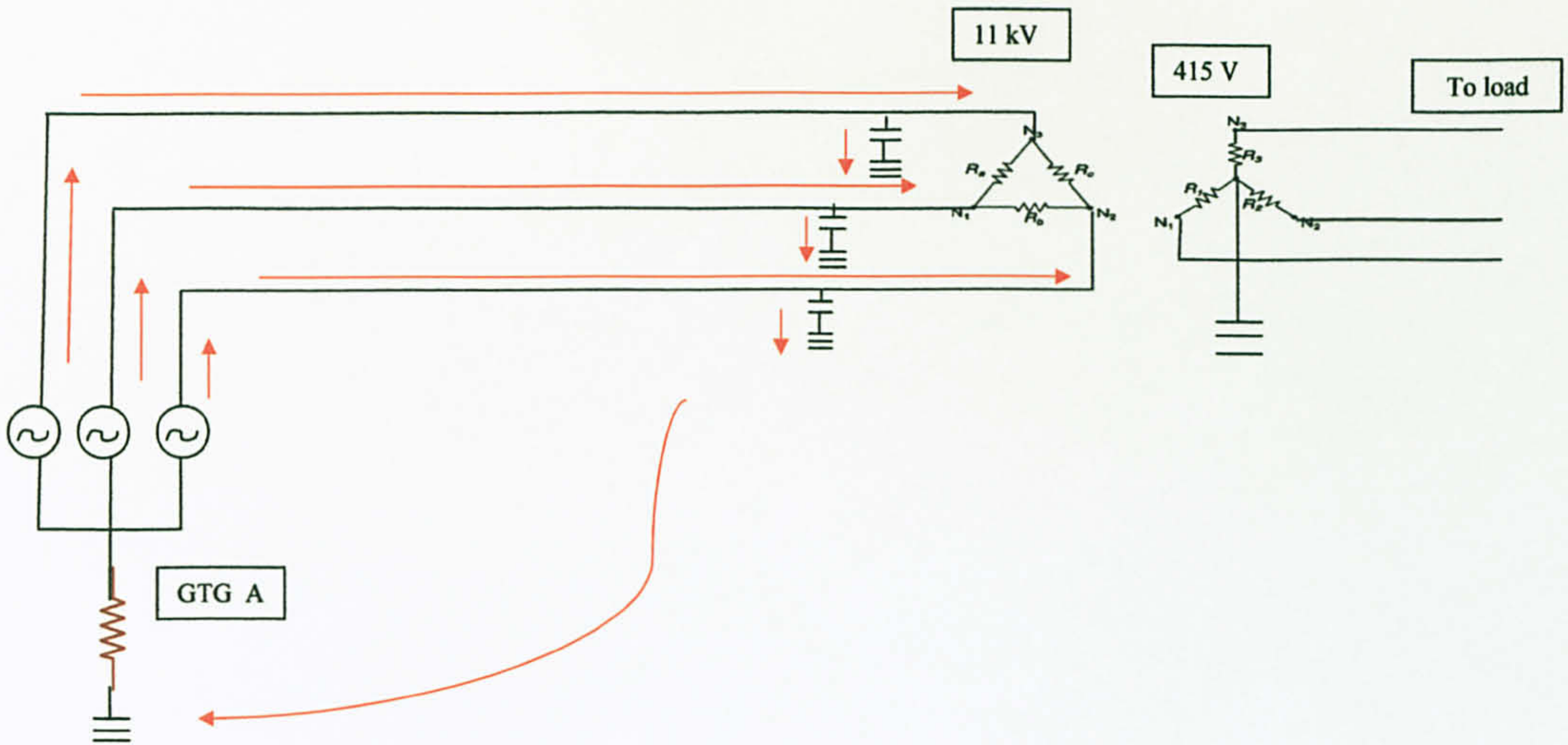


Figure 23: Flows of the triplen harmonics currents in mode 1 operation

GDC Mode 2 Operation

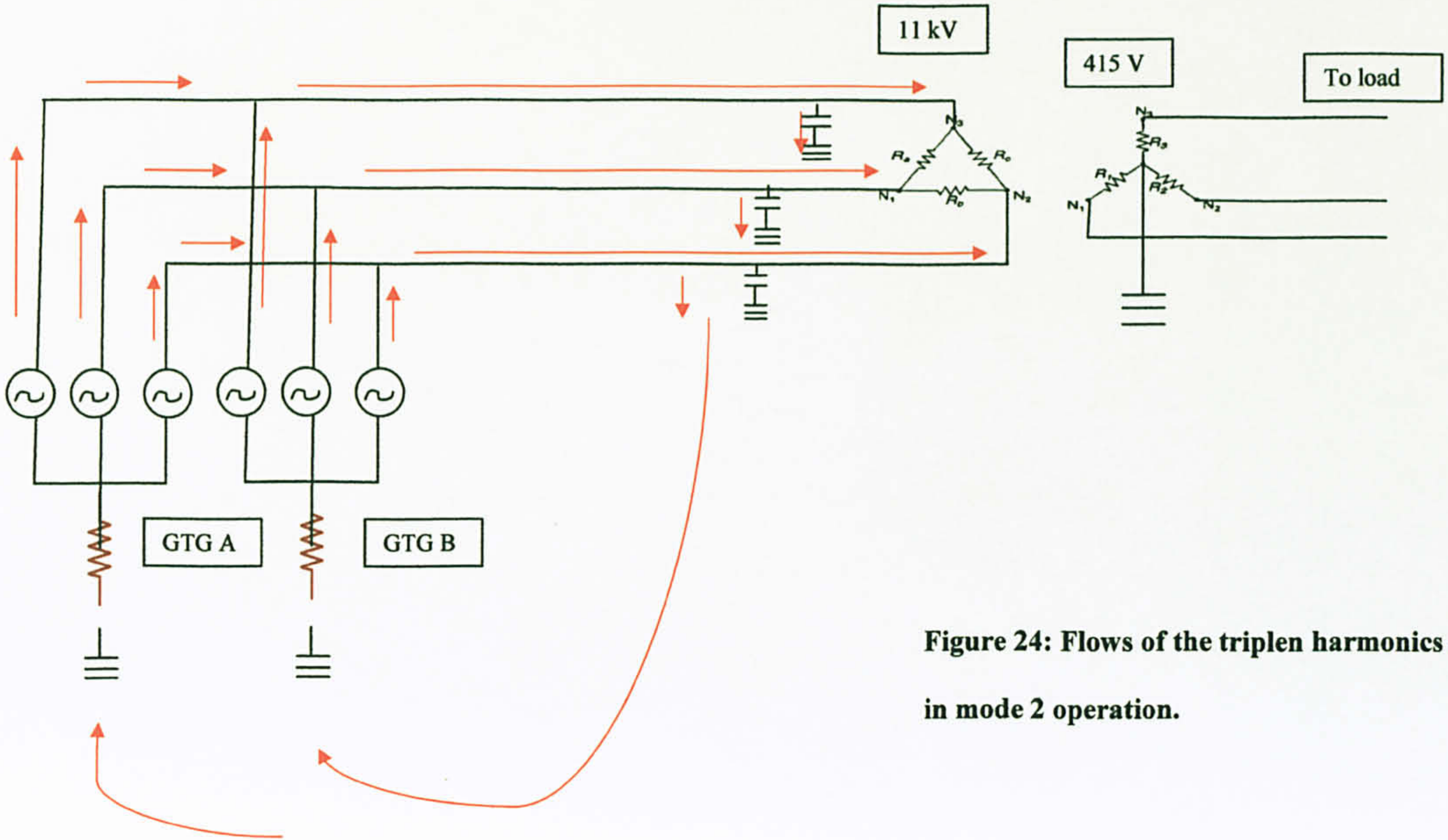


Figure 24: Flows of the triplen harmonics currents in mode 2 operation.

4.5.2 Parallel Operation

This section will show how the triplen harmonics currents flow and circulate back to the GDC's NER in parallel operation.

In parallel operation with TNB, the triplen harmonics currents flow into two paths as show in figure 26 and 27. The first path is to the TNB side and the second path is through cable capacitance. The triplen harmonics currents will flow through the easiest path that it can take. The easiest path for the triplen harmonics currents to flow is through the star connection at the TNB side. The grounded path at star connection of TNB will allow the triplen harmonics currents to circulate easily. The TNB NER is just 4Ω, therefore more triplen harmonics currents can flow through it rather than through cable to the load side.

From the measurement done on 24th and 25th March, it is show that the NER current at the TNB substation seem likely equal to the NER current at GTG.

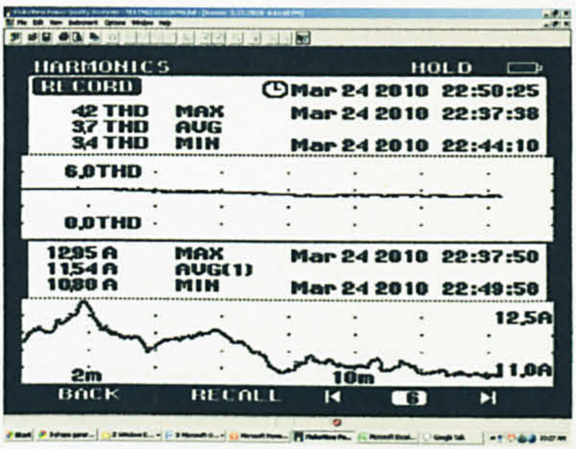


Figure 25: NER current at TNB substation on 24 March 2010

The NER current measure from the figure 39 is at average 11.54A.

Table 10: NER GTG Harmonic Current on 24 March 2010

	GTG A (A)	GTG B (A)
island	1.6	13.5
parallel	off	13.7

The NER current measure at GTG in parallel operation with TNB (Mode 3) is 13.7A.

These data shows that the triplen harmonics currents produced by GTG are flow to the TNB at about 11.55A. The rest of the triplen harmonics currents at about 2A are flow through the cable capacitance.

Harmonics from generators come from inverters and some synchronous machine. It is surprised to found that there is high current circulating on neutral when the generator is parallel to the utility system. Inverters operating in parallel are less likely to form an island if they are acting as current sources and hast destabilizing signal that is constantly trying to shift the frequency reference out of band [8].

GDC Mode 3 Operation

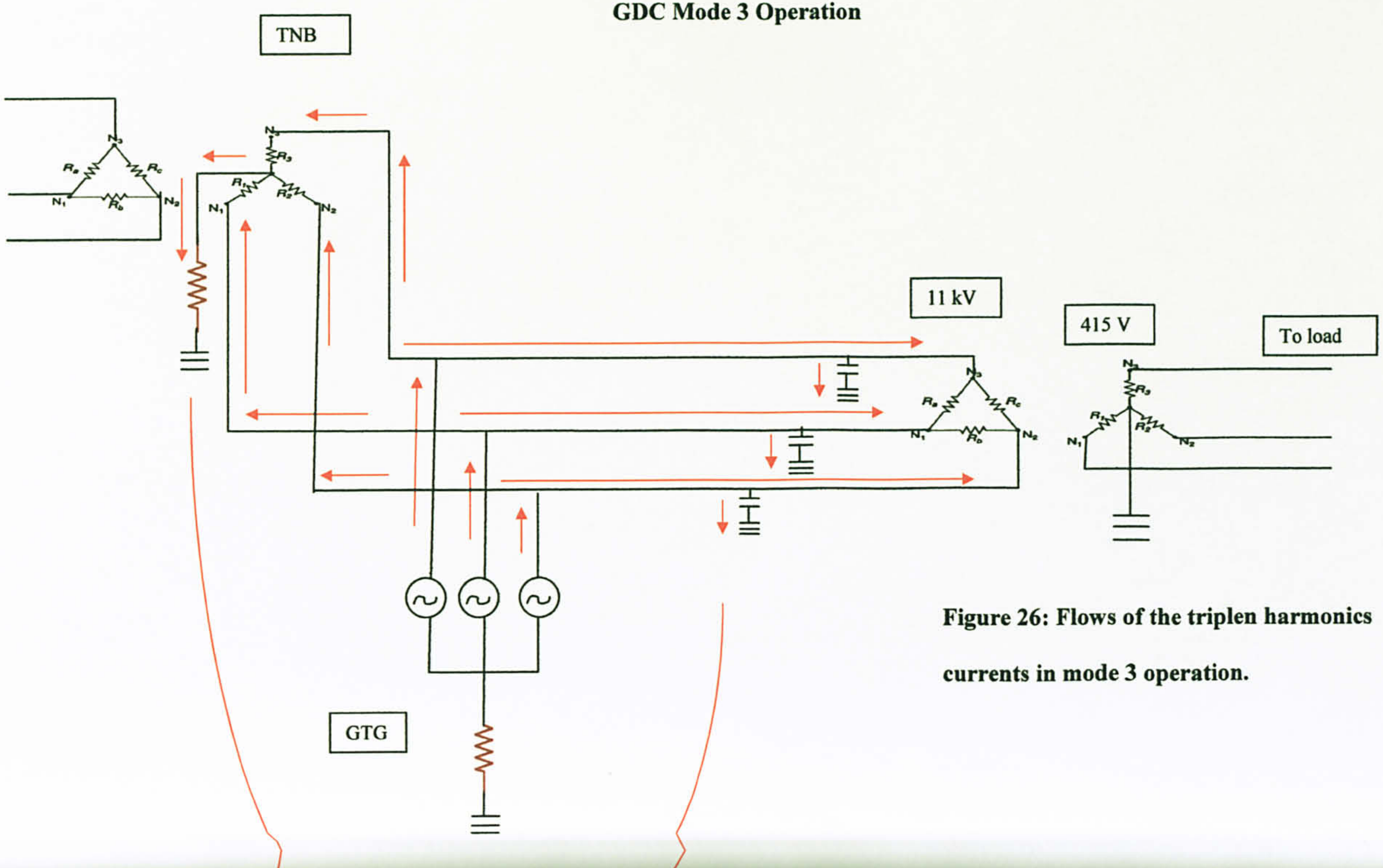


Figure 26: Flows of the triplen harmonics currents in mode 3 operation.

GDC Mode 4 Operation

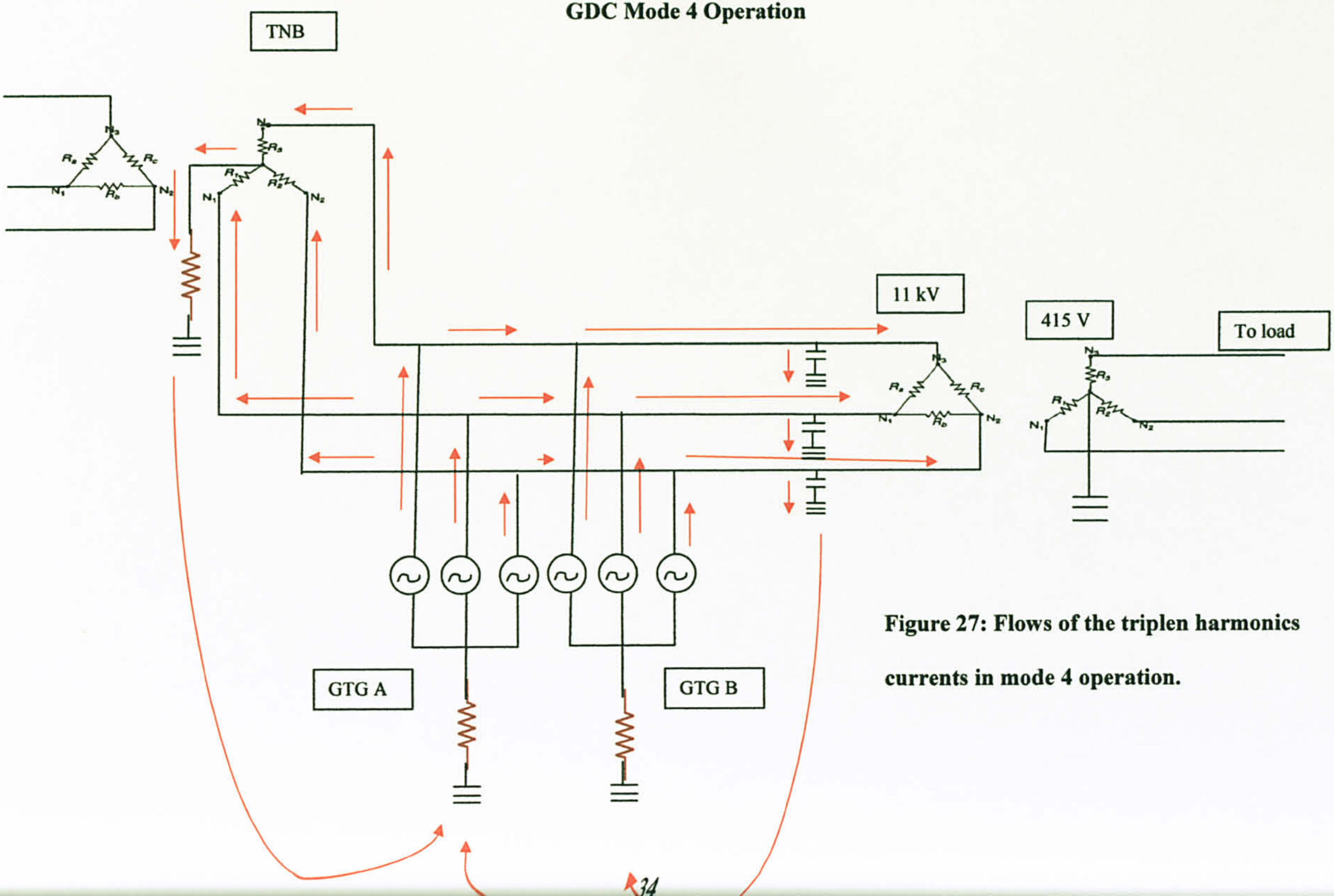


Figure 27: Flows of the triplen harmonics currents in mode 4 operation.

4.6 Analysis on GDC Modes Operations

This section will discover which mode of operations that produced the highest triplen harmonics currents. This section also will answer the issues of NER currents are higher when parallel with TNB.

4.6.1 GDC Mode 1 Operation

GDC mode 1 operation is when one GTG A operates alone in island operation. The NER current versus time on mode 1 operation is collected on 20 June 2009 as in Table 11 and being analysed as in figure 28.

Table 11: NER current of GTG A on Mode 1

Time	GTG A (A)
9:00	7.10
13:00	7.60
15:00	7.70
17:00	7.30
19:00	7.10
21:00	6.92
23:00	7.00

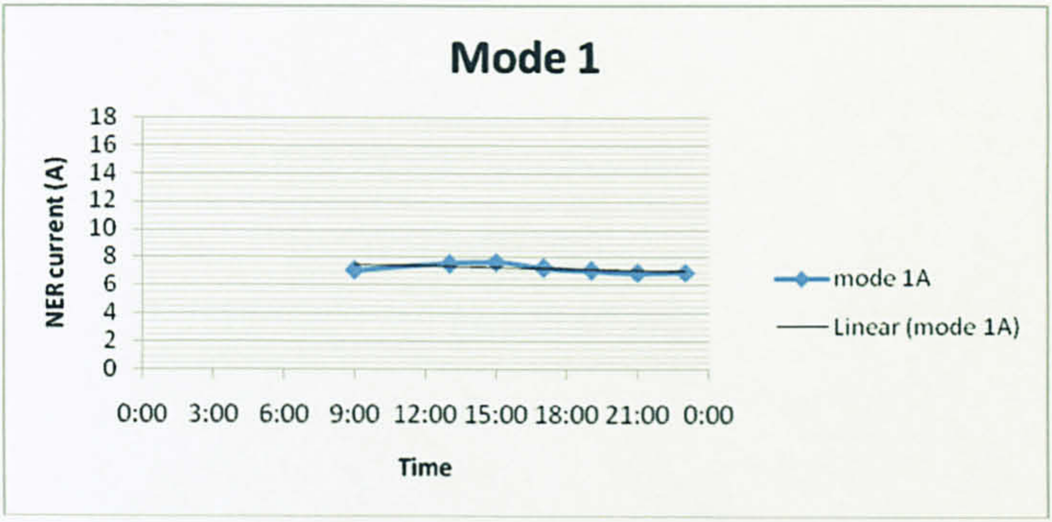


Figure 28: NER current Vs Time in mode 1 for GTG A

The average value of NER current in mode 1 from figure 29 for GTG A is 7A.

4.6.2 GDC Mode 2 Operation

GDC mode 2 operation is when two GTG's (GTG A and GTG B) operate together in island operation. The NER current versus time is collected on 30 January 2009 as in Table 12 and being analysed as in Figure 29 and Figure 30.

Table 12: NER current of GTG A and B on Mode 2

Time	GTG A (A)	GTG B (A)
9:00	4.9	3.4
13:00	4.3	4.8
15:00	3.8	5.2
17:00	4	4
19:00	3	3
21:00	3	3
23:00	2	5

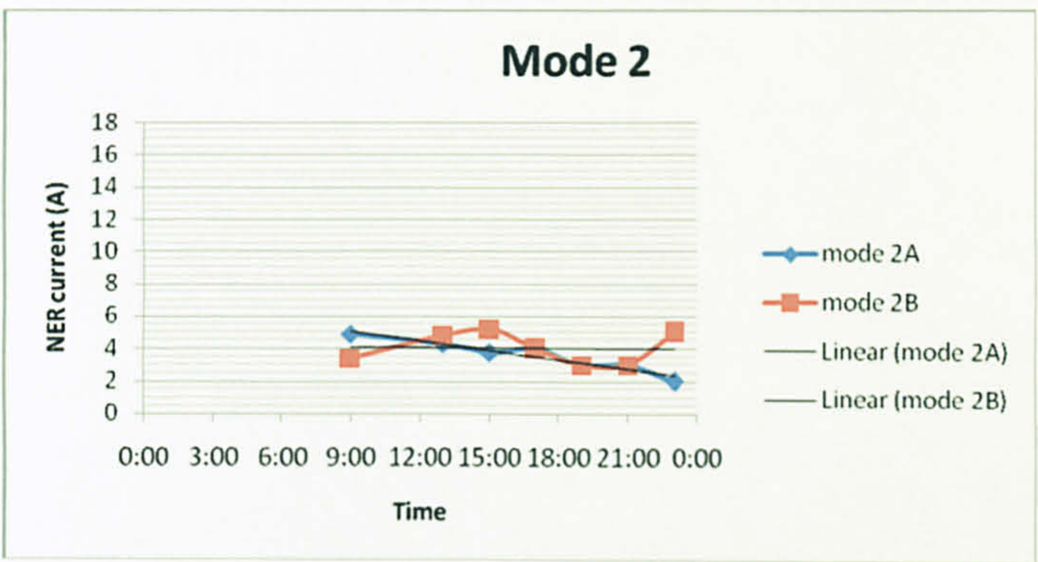


Figure 29: NER current Vs Time in mode 2 for both GTG A and GTG B

The average value of NER current in mode 2 from figure 29 for GTG A is 3.75A and GTG B is 4A.

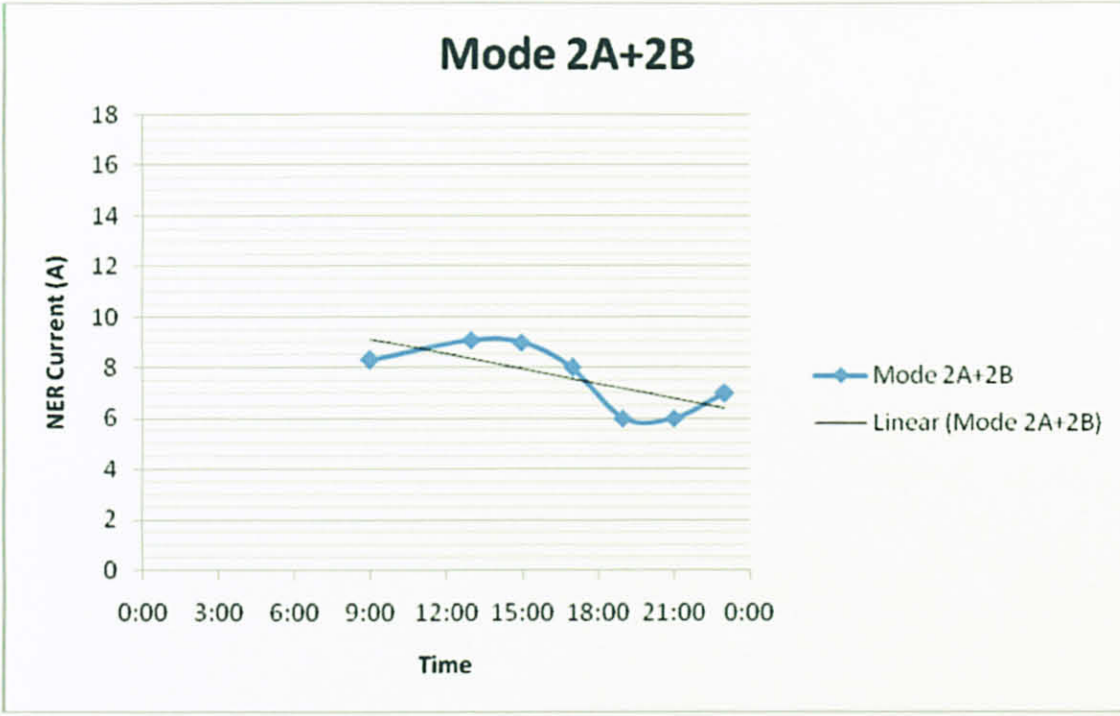


Figure 30: NER current Vs Time in mode 2 for GTG A + GTG B

The triplen harmonics current in mode 2 is sum up of two generators that operate together (average of NER current for mode 2A is 3.75A and the average of NER current for mode 2B is 4A), therefore the triplen harmonics current in mode 2 is in average of 7.75A.

4.6.3 GDC Mode 3 Operation

GDC mode 3 operation is when one GTG operates in parallel with TNB in parallel operation. The NER current versus time is collected on 21 January 2009 as in Table 13 and being analysed as in Figure 31.

Table 13: NER current of GTG A and B on Mode 3

Time	GTG A (A)
9:00	12.4
13:00	12.4
15:00	11.7
17:00	11.7
19:00	11.7
21:00	12.3

Figure 31: NER current Vs Time in mode 3 for GTG A

The average value of NER current in mode 3 from figure 31 for GTG A is 12A.

4.6.4 GDC Mode 4 Operation

GDC mode 4 operation is when two GTG's operate in parallel with TNB in parallel operation. The NER current versus time is collected on 14 July 2009 as in Table 6 and being analysed as in Figure 32 and figure 33.

Table 14: NER current of GTG A and B on Mode 4

Time	GTG A (A)	GTG B (A)
18:45	6.9	7.8
19:45	7.6	8.3
20:45	7.3	8.8
21:45	7.2	8.4
22:45	6.6	7.6

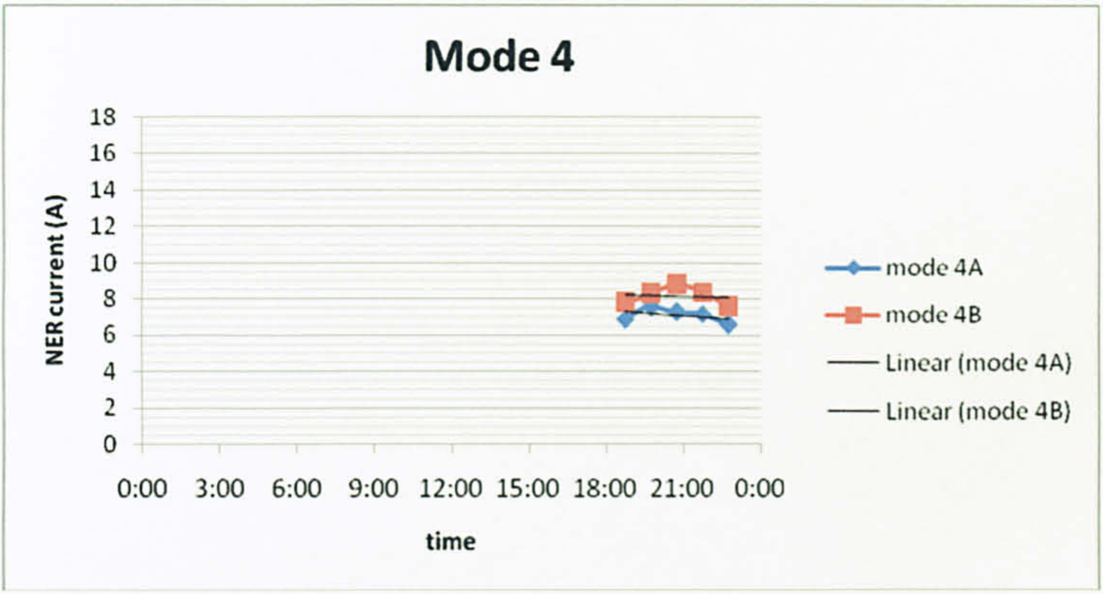


Figure 32: NER current vs Time in mode 4 for both GTG A and GTG B

The average value of NER current in mode 4 from figure 32 for GTG A is 7A and GTG B is 8A.

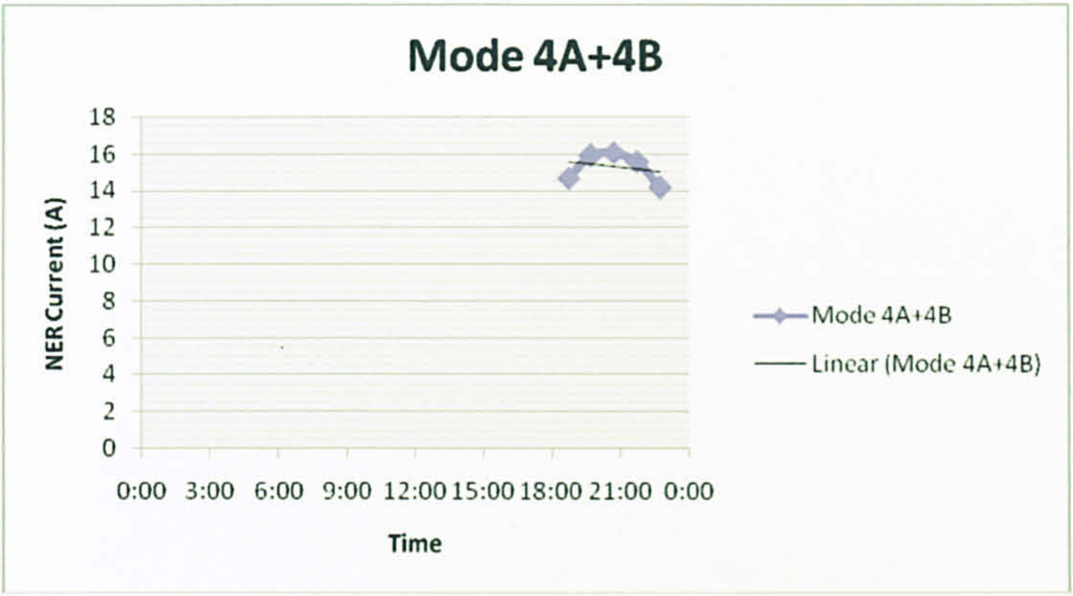


Figure 33: NER current vs Time in mode 4 for GTG A + GTG B

The triplen harmonics current in mode 4 is sum up of two generators that operate together (average of NER current for mode 4A is 7A and the average of NER current for mode 4B is 8A), therefore the triplen harmonics current in mode 4 is in average of 15A.

4.6.5 One GTG Vs Two GTG's.

This section will show the comparison of NER current produce in term of number of GTG that operates in the mode of operations. In mode 1 and mode 3, only one GTG operate at one time while in mode 2 and mode 4, two GTG's operates together at one time. This comparison will show which mode of operation will produce most triplen harmonics currents.

Island mode - One GTG (mode 1) Vs Two GTG's (mode 2)

This section is to compare the NER current using different number of GTG in island operation.

Figure 34: NER current for Mode 1 and Mode 2

From the graph in figure 34, we can see that Mode 1 (only one GTG operate) have higher NER current in average of 7A while Mode 2 (two GTG's operates together) have NER current in average of 4A for GTG A and 3.75A for GTG B.

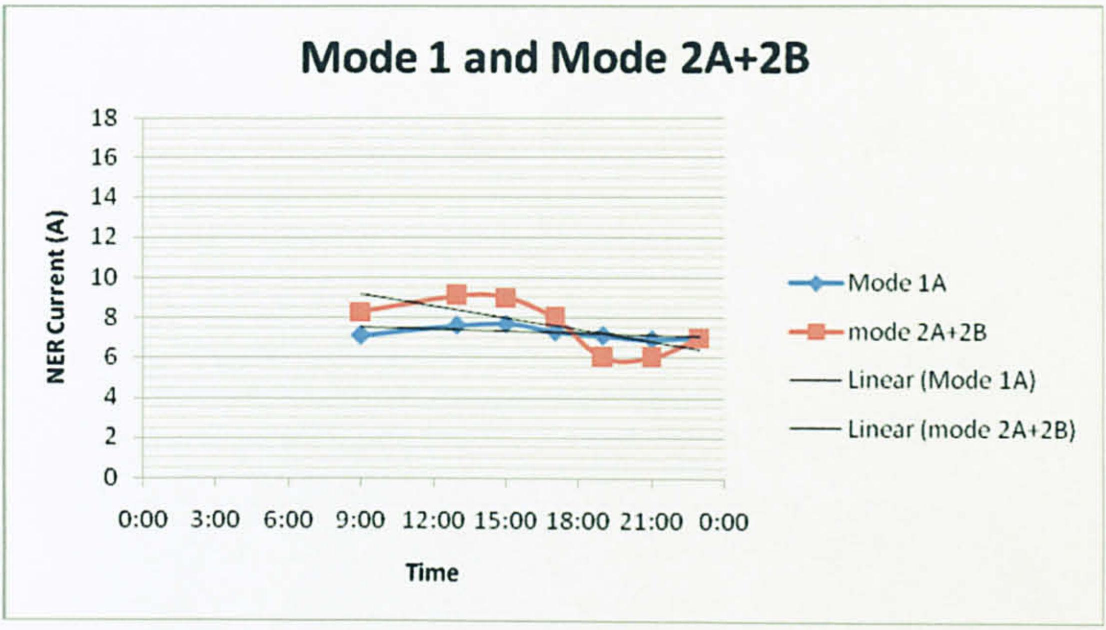


Figure 35: NER current for Mode 1 and Mode 2A+2B

The triplen harmonics currents in mode 1 are equal to NER current of one generator, GTG A, at average of 7A. The triplen harmonics currents in mode 2 is sum up of two generators that operate together (average of NER current for mode 2A is 3.5A and the average of NER current for mode 2B is 4A), therefore the triplen harmonics currents in mode 2 is in average of 7.5A. In figure 35, we can see that the average of NER current in mode 2 operation is slightly higher than the average of NER current produce by mode 1 operation.

Parallel Mode - One GTG (mode 3) Vs Two GTG's (mode 4)

This section is to compare the NER current using different number of GTG in parallel operation.

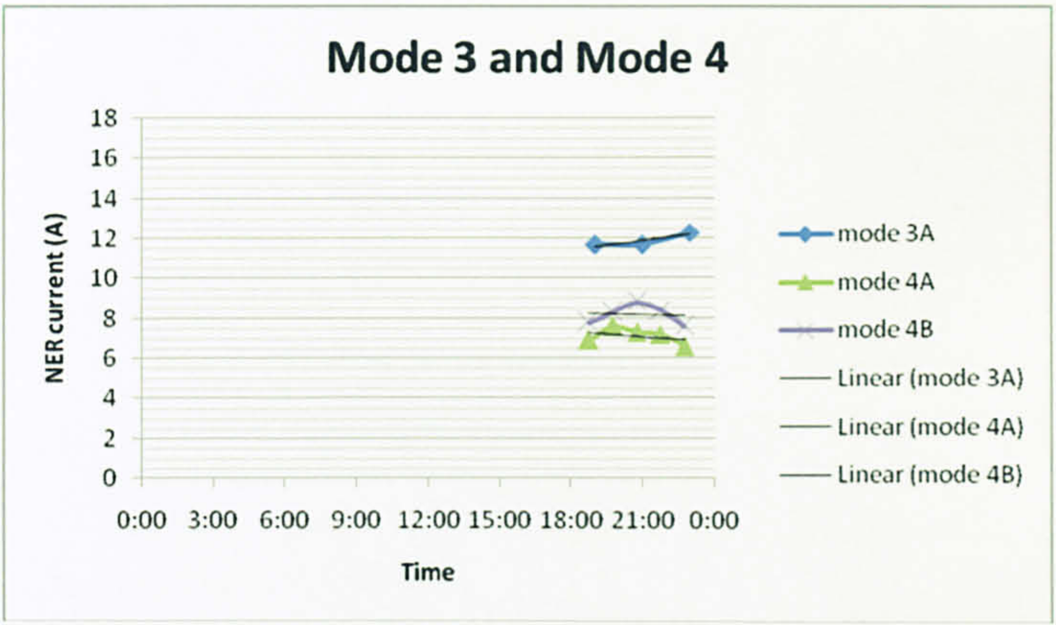


Figure 36: NER current for Mode 3 and Mode 4

From figure 36, mode 3A have more NER current with average of 12 A, while mode 4 have NER current with averages of 7A and 8A.

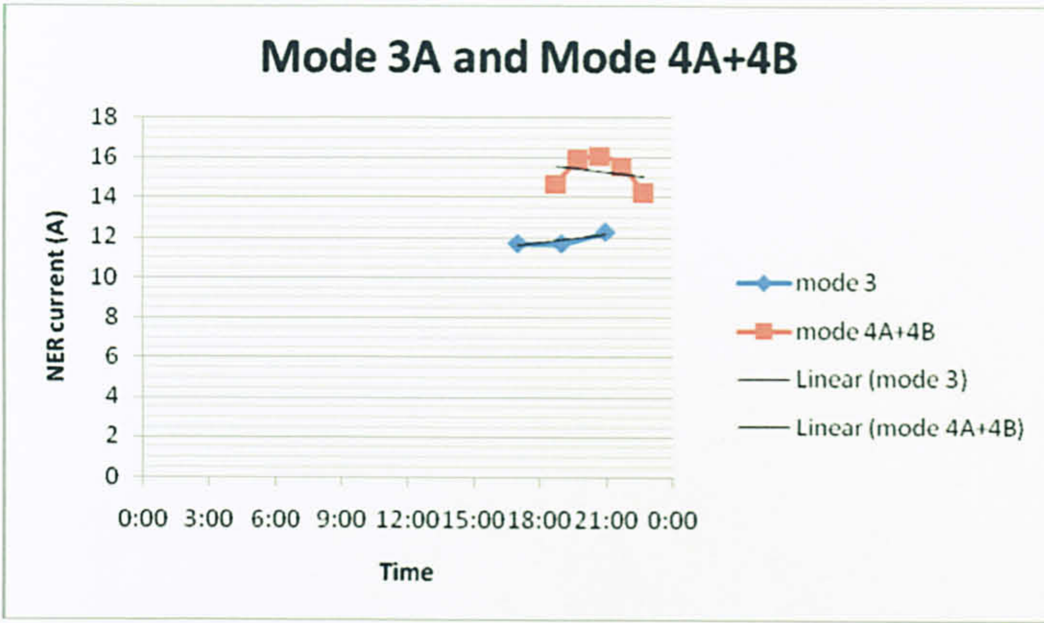


Figure 37: NER current for Mode 3 and Mode 4A+4B

When two GTG's operates together, the triplen harmonics currents in mode 4 become in average of 15A. Mode 4 having the most triplen harmonics currents compare to all modes of operation. However, generator in mode 3 produced the highest triplen harmonics current.

From the comparison between all the graphs in this section, we can conclude that the operation with two GTG's produce more triplen harmonics currents than the operation with one GTG. This happen because of the third harmonic current, which is generated, will sum up together causing a significantly higher current flow in neutral conductor. Therefore the more GTG's operates together, the more triplen harmonics currents will be produce.

4.6.6 Island Vs Parallel Mode.

This section will show the comparison of NER current in different mode of operations in GDC. This comparison will show which operation that produced most triplen harmonics currents.

Island (Mode 1) Vs Parallel (Mode 3)

This section is to compare the NER current in different mode of operation using one GTG.

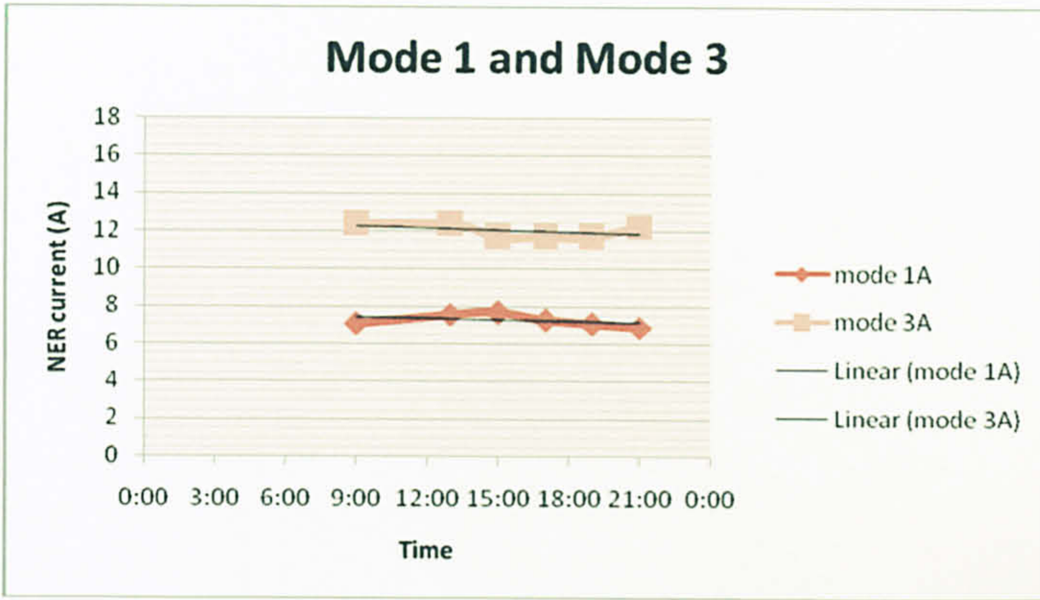


Figure 38: NER current for Mode 1 and Mode 3 for GTG A.

Figure 38 shows the comparison between mode 1 in island operation and mode 3 in parallel operation. Mode 3 have more NER current with an average of 12A while mode 1 is have less NER current with average of 7A. Here we can see that the parallel operation (mode 3) produce more triplen harmonics currents than the island operation (mode 1).

Island (Mode 2) Vs Parallel (Mode 4)

This section is to compare the NER current in different mode of operation using two GTG.

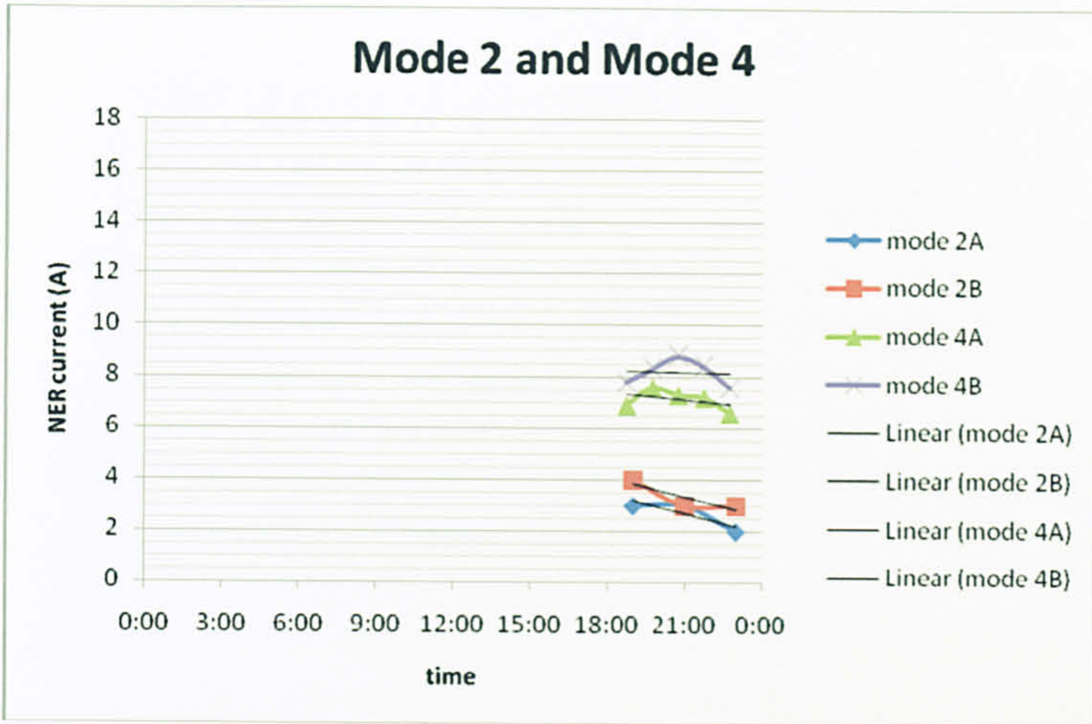


Figure 39: NER current for Mode 2 and Mode 4 for Both GTG's.

Figure 39shows the comparison between mode 2 in island operation and mode 4 in parallel operation. From the figure, we can see that mode 4A and 4B produce more NER current than mode 2A and 2B.

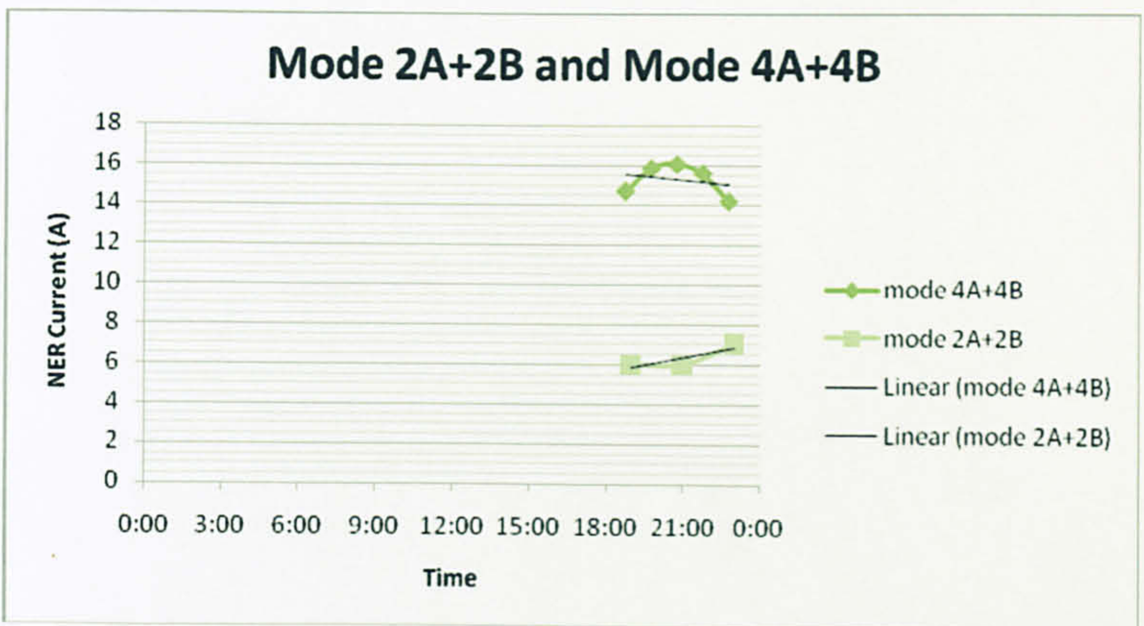


Figure 40: NER current for Mode 2A+2B and Mode 4A+4B

The triplen harmonics currents are sum up of NER current in generators that operate together in that operation. Therefore when two GTG's operates together in island operation (mode 2) and parallel operation (mode 4) , the triplen harmonics currents are calculated as sum up of NER current of GTG A and GTG B. In island operation (mode 2), the triplen harmonics currents are in an average of 7.75A while in parallel operation (mode 4), the triplen harmonics currents are in average of 15A. From here we can said that the parallel operation (mode 4) having more triplen harmonics currents than the island operation (mode 2).

From the graphs comparison above, we can conclude that the parallel operation produced more triplen harmonics currents than the island operation because of the path that can be take by the triplen harmonics currents to circulate is various, through TNB NER and cable. While the star connection at TNB give the triplen harmonics currents the easiest way to flow through.

4.7 The Relationship Between NER Current and Power

The measurement below is taking on 12 April 2010.

Table 15: The load and NER current

time(m)	load(kW)	I ner (A)
0	2878	4.28
1	2300	12.48
2	2100	6.82
3	1700	5.08
4	1400	3.58
5	1000	2.41
6	500	1.25

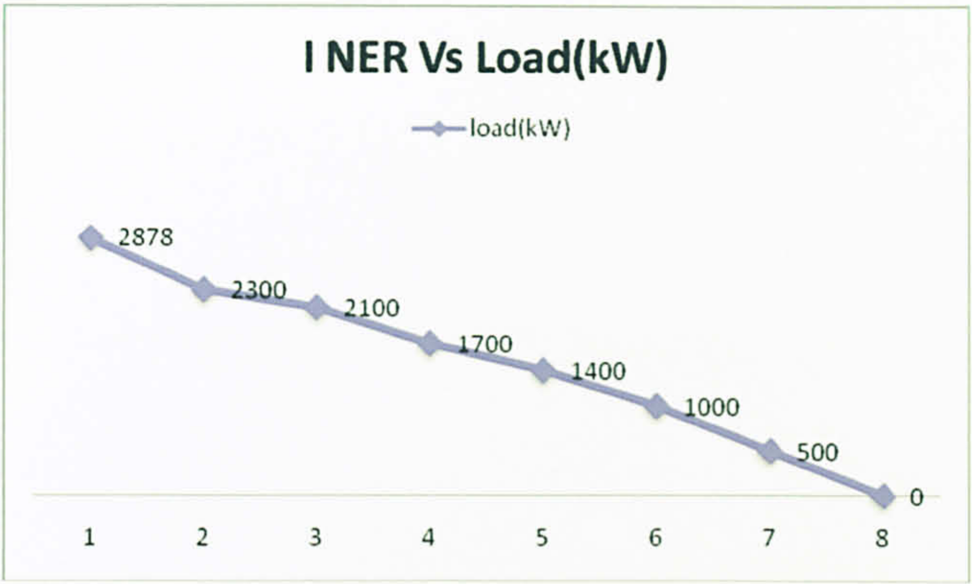


Figure 41: I NER Vs Load

From figure 41, the NER current will be high when the load is high. Therefore the triplen harmonics currents will be high when the load is high. According to the load demand, the load is high during the day and lower at night. Therefore, the triplen harmonics currents produce on the the day is higher than the night.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Triplen harmonics currents are exist in every mode of operations. Mode 4 has the highest triplen Harmonics currents, while generator in mode 3 produced the highest harmonics currents. Parallel operation giving more opportunity to the triplen harmonics currents to flows in the system, therefore NER current is higher when in parallel operation. The operation with two GTG's produced more triplen harmonics currents in the system.

The triplen harmonics is being produced by the Generator and circulates back to the GTG's NER. The load and TNB does not contribute to the existence of harmonics at the GDC plant. The more load, more NER current produce and more triplen harmonics currents exist in the system. The more triplen harmonics current exist, the less capability of the generator thermal to limit the thermal existence in the generator. When this happen, the temperature will higher and effects the plant equipments.

Figure 42 : Wire broken at GTG's NER

5.2 RECOMMENDATION

5.2.1 The Zig-Zag Earthing Transformer

The generators should be earthed through zig zag earthing transformers connected to the ll-kV busbars.

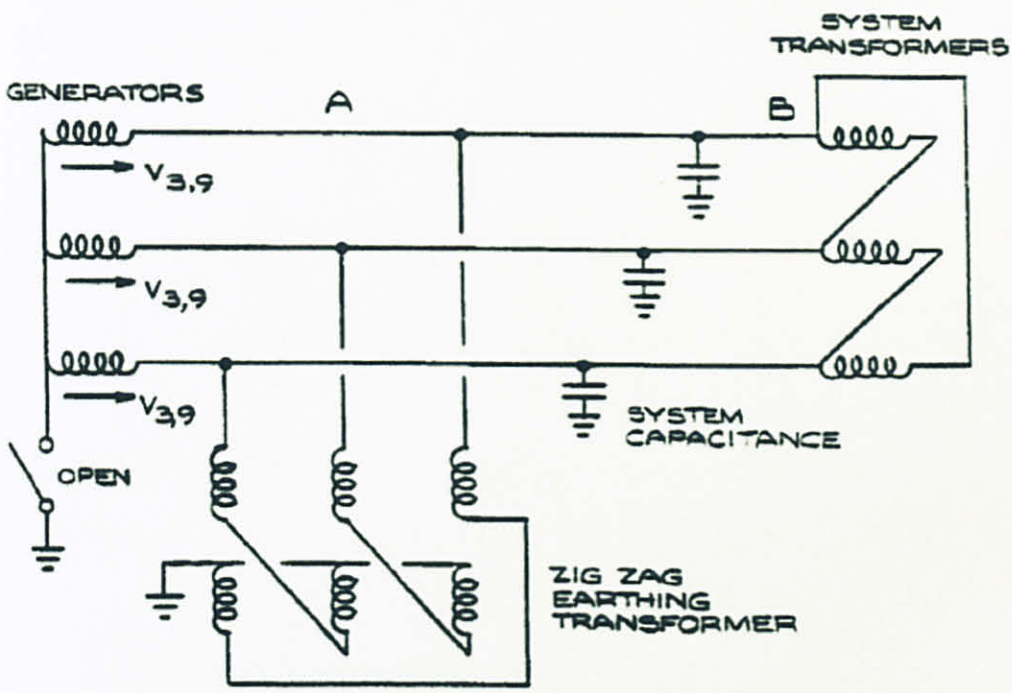


Figure 43 : Zig-Zag earthing Transformer

As with other three-phase transformers, the zigzag transformer contains coils on three cores. The first coil on each core is connected contrariwise to the second coil on the next core. The second coils are then all tied together to form the neutral and the phases are connected to the primary coils. Each phase, therefore, couples with each other phase and the voltages cancel out. As such, there would be negligible current through the neutral pole and it can be tied to ground. If one phase or faults to earth, the voltage applied to each phase of the transformer is no longer in balance, the fluxes in the windings no longer oppose. Zero sequence current exists between the transformers neutral to the faulting phase. Hence, the zigzag transformer will provide a return path for earth faults on delta-connected systems.

5.2.2 The Passive filter

The purpose of applying passive filter is to provide a low impedance path for harmonics currents so that they flown in the filter and not in the supply.

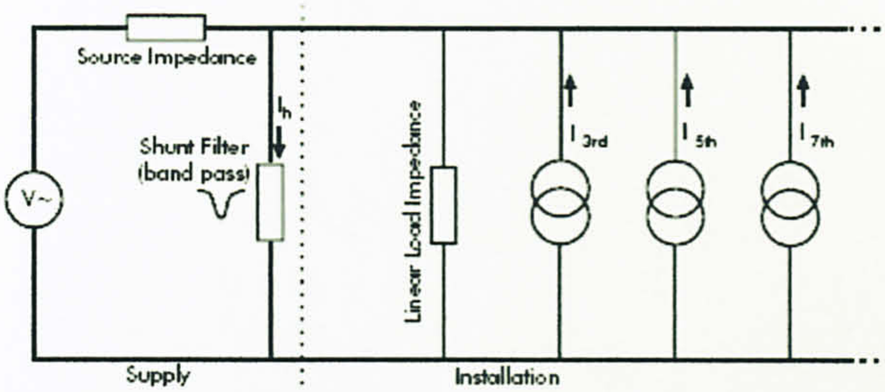


Figure 44: Passive harmonics shunt filter

The filter can be designed accordingly to the requirements while the complex filter is used to increase the series impedance at harmonics frequencies and reduce the proportion of currents that flows back onto the supply

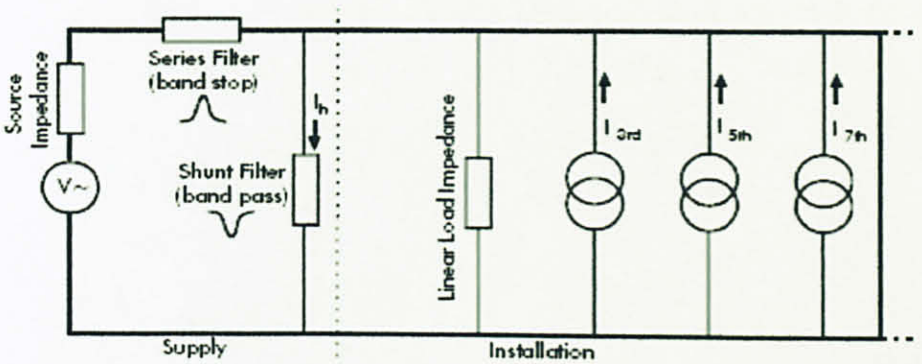


Figure 45: Passive series and shunt filter

The filter is more on to block the harmonics current than provide a controlled path for the current so that the large harmonics voltage can drop across the supply of the load side. Series filters are very useful in certain circumstance but not recommended as a general purpose solution.

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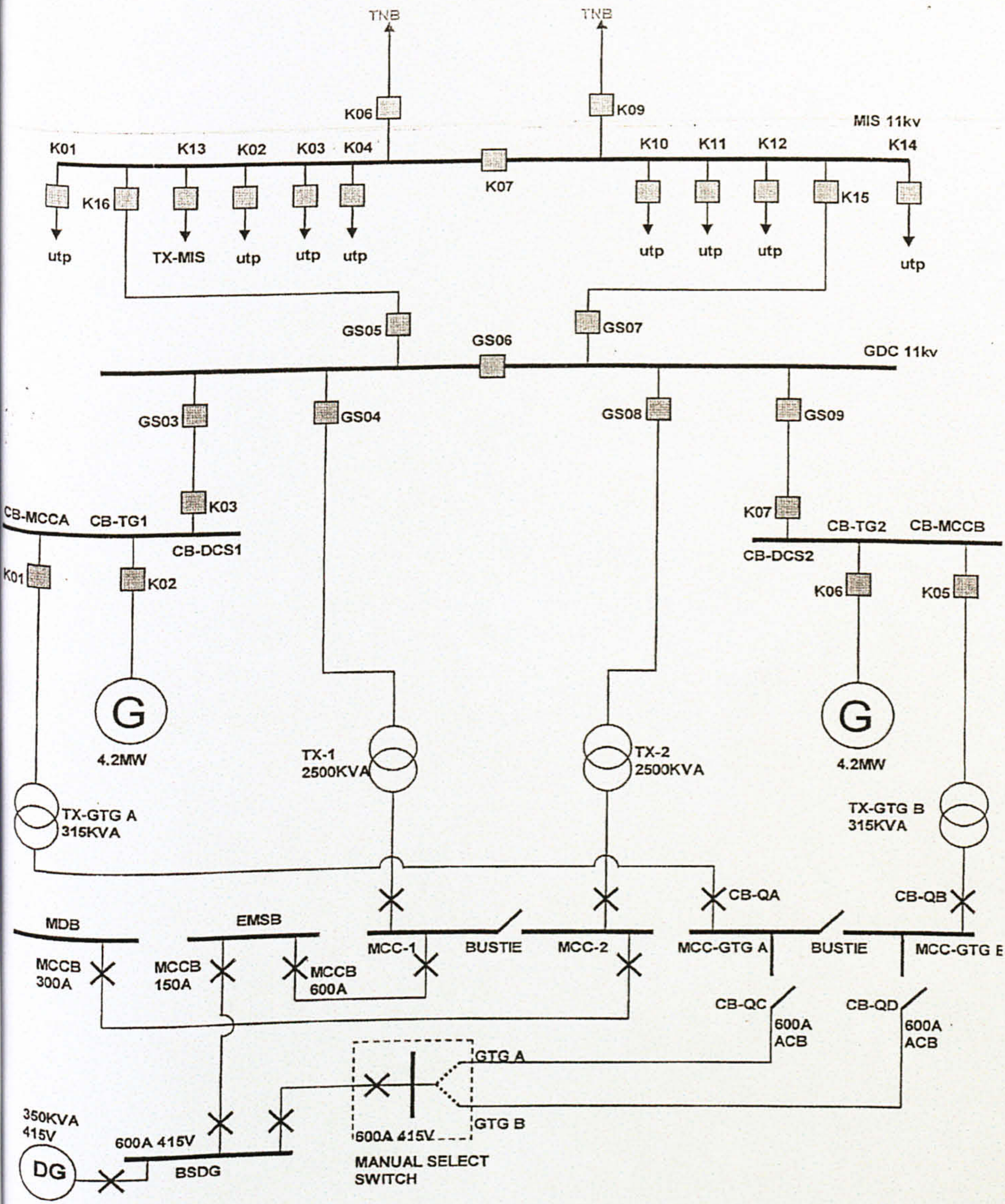
APPENDICES

11 KV SINGLE LINE DIAGRAM



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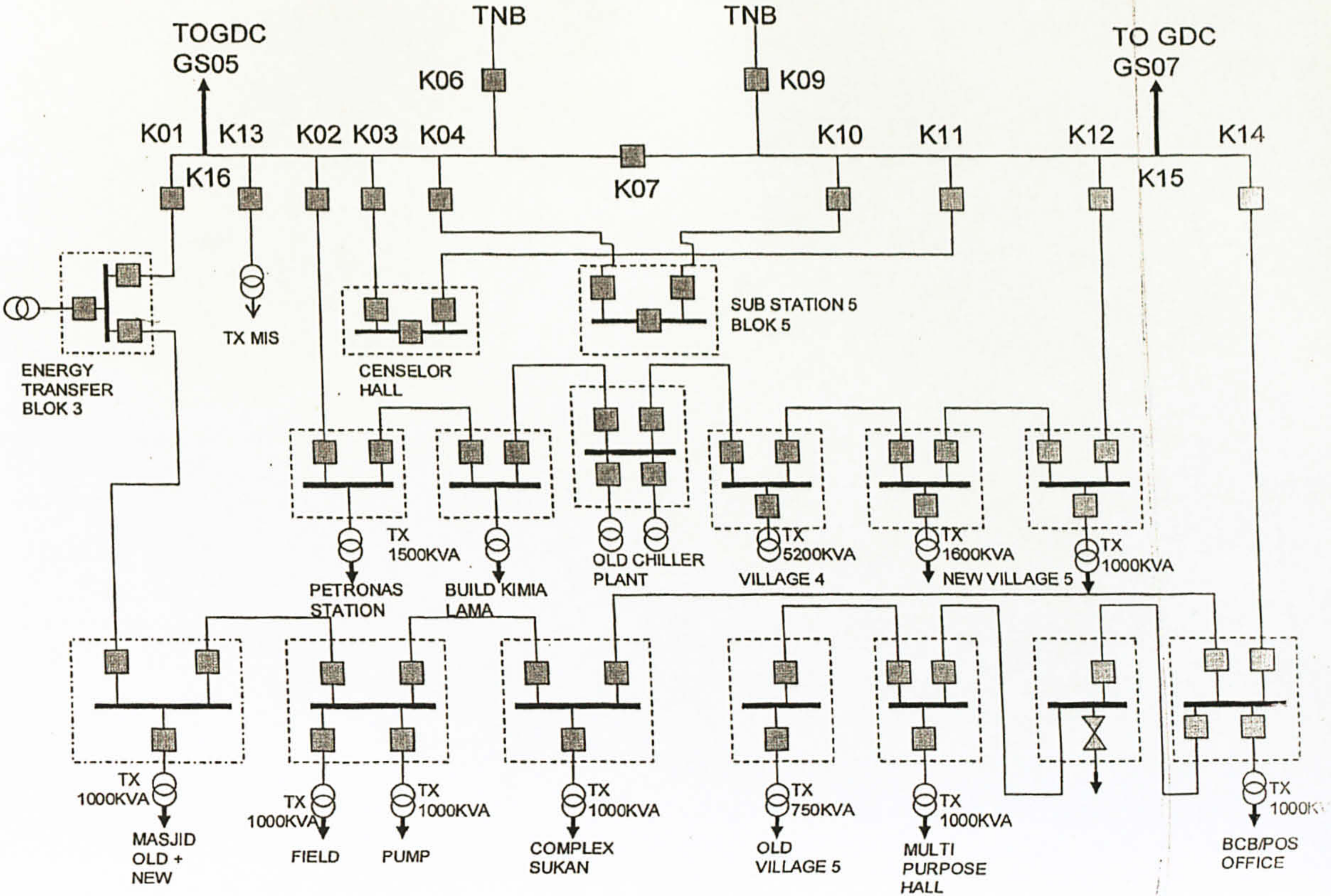
SINGLE LINE DIAGRAM UTP



GAS TURBINE DAILY READING - DAY SHIFT

PARAMETER NAME	UNITS	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B
MODE		ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP
TIME	HRS	0800		1000		1200		1400		1600		1800	
DATE 30/1/09													
NGP	%	100	100	100	100	100	100	100	100	100	100	100	100
KW	KW	3352	2913	3363	2875	3387	3191	3577	3436	3524	3634	2836	2973
PCD	KPAG	785.6	712.0	784.3	702.1	800.9	773.0	849.3	828.1	846.0	887.1	701.4	720.0
AIR INLET DP	KPAD	0.49	0.55	0.53	0.55	0.57	0.60	0.58	0.66	0.62	0.72	0.42	0.54
T1	DEG C	27.5	27.4	28.1	27.7	33.3	32.2	34.4	33.1	35.4	34.9	28.9	26.8
T5 AVERAGE	DEG C	657	634	650	622	647	618	641	629	641	617	656	642
ENCLOSURE TEMP	DEG C	46.1	49.2	46.7	48.9	52.3	55.8	54.9	59.0	56.2	61.8	45.6	50.6
FUEL SYSTEM													
MIN FUEL	%	12.2	12.8	12.2	12.8	12.1	12.7	12.1	12.7	12.1	12.7	12.2	12.8
FUEL GAS PRESSURE	KPA	1811.4	1818.0	1797.0	1810.4	1802.3	1806.0	1798.4	1801.7	1797.0	1798.4	1807.5	1808.2
FUEL GAS FLOW	KG/HR	936.7	894.7	937.7	881.3	935.2	930.8	959.4	972.8	985.1	1022.7	859.1	902.1
GAS VALVE CHECK	KPAD	1839.0	1873.1	1831.1	1874.8	1825.8	1864.2	1825.8	1860.7	1824.5	1858.9	1835.1	1866.0
GAS CTR DP	KPAD	76.4	82.5	76.1	77.3	72.2	68.7	74.8	85.6	73.1	85.1	72.0	84.2
LUBE OIL SYSTEM													
HEADER TEMP	DEG C	61.1	53.3	61.0	53.6	62.2	58.7	63.7	59.4	64.2	60.4	61.4	50.1
HEADER PRESSURE	KPAG	368.2	417.4	364.8	415.5	348.1	413.2	344.1	408.2	342.5	406.4	376.3	418.3
TANK TEMP	DEG C	73.7	66.8	73.6	66.8	74.7	71.7	76.3	72.2	77.2	73.7	72.4	64.2
GP THRUST BRG	DEG C	84.8	73.1	84.7	73.1	85.4	78.8	87.6	80.9	88.1	83.3	80.2	71.3
DRIVEN END BRG	DEG C	72.3	75.4	72.3	74.8	73.7	79.1	74.9	77.6	75.7	79.4	72.6	73.5
EXCITER END BRG	DEG C	77.0	71.2	77.0	70.7	77.8	75.4	79.1	73.3	79.7	76.1	76.8	69.8
GENERATOR													
REACTIVE POWER	KVAR	1435	1385	1370	1315	1465	1280	1695	1425	1705	1420	1130	1320
POWER FACTOR		-.92	-.91	-.93	-.91	-.92	-.94	-.90	-.93	-.90	-.93	-.93	-.91
FREQUENCY	Hz	50	50	50	50	50	50	50	50	50	50	50	50
VOLTAGE	V	11254	11285	11274	11295	11233	11295	11222	11274	11212	11264	11233	11264
CURRENT	A	184	162	185	162	183	176	200	191	200	196	155	162
VIBRATION													
GP B 3	um	17.1	4.8	16.5	5.1	16.7	4.6	16.7	4.7	16.7	4.4	16.7	4.4
GP B 2	um	3.5	13.0	3.3	12.7	3.4	13.5	2.8	13.1	3.0	12.7	2.4	11.1
GP B 1	um	31.7	13.0	32.2	13.3	32.0	13.9	32.5	14.7	34.2	15.7	28.6	11.8
PANEL OPERATOR				MUHAIMIN			JASNI		FAIRUS			FAKHRUL	

GAS TURBINE DAILY READING - NIGHT SHIFT

PARAMETER NAME	UNITS	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B
MODE		ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP
TIME	HRS	2000		2200		0000		0200		0400		0600	
DATE													
NGP	%	100.0	100.0	100.0	100.0		100.0		100.0		100.0		100.0
KW	KW	2524	2579	1796	2416		3566		2892		2527		2550
PCD	KPAG	689.0	655.0	916.2	624.5		834.0		689.5		690.4		643.1
AIR INLET DP	KPAD	0.29	0.48	0.81	0.44		0.62		0.52		0.43		0.45
T1	DEG C	28.1	26.8	27.9	25.9		28.1		26.6		25.8		27.1
T5 AVERAGE	DEG C	649	637	426	627		822		626		629		624
ENCLOSURE TEMP	DEG C	42.9	48.2	49.4	47.2		51.9		49.0		48.4		48.8
FUEL SYSTEM													
MIN FUEL	%	12.2	12.8	12.2	12.8		12.8		12.8		12.8		12.8
FUEL GAS PRESSURE	KPA	1807.2	1812.6	1814.0	1813.7		1827.8		1815.8		1828.9		1835.4
FUEL GAS FLOW	KG/HR	814.2	844.8	729.0	823.2		984.6		903.1		825.0		827.8
GAS VALVE CHECK	KPAD	1836.4	1869.5	1843.0	1875.7		1886.4		1876.6		1897.8		1892.5
GAS CTR DP	KPAD	72.2	79.1	62.0	77.7		89.4		83.8		78.4		78.4
LUBE OIL SYSTEM													
HEADER TEMP	DEG C	60.4	52.6	60.8	52.2		53.6		53.0		52.9		52.8
HEADER PRESSURE	KPAG	369.5	419.7	370.2	421.6		414.8		416.3		421.9		419.9
TANK TEMP	DEG C	72.2	65.8	73.3	65.2		67.2		66.3		65.8		65.9
GP THRUST BRG	DEG C	74.3	71.9	83.2	71.1		73.7		72.7		71.8		71.5
DRIVEN END BRG	DEG C	71.8	73.9	72.3	74.2		73.6		75.8		73.2		74.3
EXCITER END BRG	DEG C	76.5	70.1	76.7	70.6		69.9		71.6		70.0		70.2
GENERATOR													
REACTIVE POWER	KVAR	1135	965	720	1070		1655		1095		910		930
POWER FACTOR		-0.91	-0.93	-0.93	-0.92		-0.90		-0.93		-0.95		-0.94
FREQUENCY	Hz	50.0	50.0	50.0	50.0		50.0		50.0		50.0		50.0
VOLTAGE	V	11243	11254	11160	11233		11327		11410		11274		11316
CURRENT	A	140	142	96	122		205		148		135		132
VIBRATION													
GP B 3	um	16.4	4.6	16.4	4.7		4.6		4.6		4.5		5.1
GP B 2	um	3.8	12.5	5.4	11.4		11.9		11.3		12.0		12.6
GP B 1	um	28.6	11.4	32.6	11.0		11.4		10.7		11.5		11.5
PANEL OPERATOR		MUHAIMIN				JASNI				FAIRUS		FAKHRUL	

GAS TURBINE DAILY READING - DAY SHIFT

PARAMETER NAME	UNITS	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B
MODE		$\boxed{\text{ISOCH}}$/ DROOP	ISOCH/ DROOP	$\boxed{\text{ISOCH}}$/ DROOP	ISOCH/ DROOP	$\boxed{\text{ISOCH}}$/ DROOP	ISOCH/ DROOP	$\boxed{\text{ISOCH}}$/ DROOP	ISOCH/ DROOP	$\boxed{\text{ISOCH}}$/ DROOP	ISOCH/ DROOP	$\boxed{\text{ISOCH}}$/ DROOP	ISOCH/ DROOP
TIME	HRS	0800		1000		1200		1400		1600		1800	
DATE	21/1/09												
NGP	%	100.0		99.9		100.1		99.8		99.9		100.0	
KW	KW	3745		3926		3856		3993		3946		3810	
PCD	KPAG	854.6		896.4		909.6		969.9		936.6		891.0	
AIR INLET DP	KPAD	0.59		0.65		0.72		0.73		0.71		0.65	
T1	DEG C	27.9		29.8		34.0		35.9		35.7		32.9	
T5 AVERAGE	DEG C	653		649		643		643		646		643	
ENCLOSURE TEMP	DEG C	47.7		50.8		54.8		58.7		58.7		56.4	
FUEL SYSTEM													
MIN FUEL	%	12.0		12.0		11.9		11.9		11.9		11.9	
FUEL GAS PRESSURE	KPA	1826.2		1802.3		1815.3		1816.6		1798.4		1797.0	
FUEL GAS FLOW	KG/HR	1018.2		1026.7		1027.6		1054.3		1035.1		1006.4	
GAS VALVE CHECK	KPAD	1845.7		1831.1		1840.4		1841.0		1832.4		1820.5	
GAS CTR DP	KPAD	62.5		84.9		81.4		77.5		80.0		80.5	
LUBE OIL SYSTEM													
HEADER TEMP	DEG C	61.1		60.6		60.8		63.1		63.3		61.1	
HEADER PRESSURE	KPAG	330.6		322.4		316.5		306.7		308.5		311.4	
TANK TEMP	DEG C	74.1		74.2		74.8		77.2		76.6		75.3	
GP THRUST BRG	DEG C	81.9	N/O	85.0		85.8		87.6		85.2		80.1	
DRIVEN END BRG	DEG C	72.6		72.9		73.4		75.2		75.2		74.3	
EXCITER END BRG	DEG C	77.2		77.1		77.9		79.4		79.4		78.4	
GENERATOR													
REACTIVE POWER	KVAR	1575		1560		1545		1580		1586		1535	
POWER FACTOR		-0.92		-0.93		-0.93		-0.93		-0.93		-0.93	
FREQUENCY	Hz	50.0		50.0		50.0		49.9		50.0		50.0	
VOLTAGE	V	11348		11201		11358		11316		11295		11327	
CURRENT	A	209		218		215		211		214		208	
VIBRATION													
GP B 3	um	11.9		12.3		12.5		17.0		14.1		13.4	
GP B 2	um	6.4		6.5		6.3		5.4		4.9		5.5	
GP B 1	um	32.2		33.6		33.1		33.7		32.9		31.8	
PANEL OPERATOR				$\boxed{\text{MUHAIMIN}}$/NORDIN.		JASNI			FAIRUS			FAKHRUL	

UNITS		GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B	GTG A	GTG B
MODE		ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP	ISOCH/ DROOP
TIME	HRS	2000		2200		0000		0200		0400		0600	
DATE													
NGP	%	100		100		100		100		100		100	
KW	KW	3857		3987		3626		3405		3329		3119	
PCD	KPAG	891		898.3		838-0		796-2		804-2		745-2	
AIR INLET DP	KPAD	0.62		0,62		0-58		0.54		0-55		0.46	
T1	DEG C	30.7		26.4		26-8		26-2		26.1		27.1	
T5 AVERAGE		647		651		654		650		651		655	
ENCLOSURE TEMP		52.3		61-6		46.3		44-8		43.9		42.7	
FUEL SYSTEM													
MIN FUEL	%	12.0		12-0		12. 0		12-0		12-0		12.0	
FUEL GAS PRESSURE	KPA	1791-8		1802.3		1820-6		1834-9		1798-4		1802.3	
FUEL GAS FLOW	KG/HR	1025.7		1041-5		991.6		958-0		952-9		914-9	
GAS VALVE CHECK	KPAD	1829.4		1829.8		1851.0		1864-2		1828-4		1845.7	
GAS CTR DP	KPAD	81.8		85.5		83.4		81-3		81-8		79.6	
LUBE OIL SYSTEM													
HEADER TEMP	DEG C	59.3		61.6		59.1		61-6		61-5		61-3	
HEADER PRESSURE	KPAG	321-1		335-9		333.2		335-9		337-0		337.7	
TANK TEMP	DEG C	72.8		74.0		72-5		73-6		73-7		73.1	
GP THRUST BRG		77.7		81.1		80.0		80-6		80.4		80.9	
DRIVEN END BRG		72.3		72-7		71-8		72-6		72-7		72.3	
EXCITER END BRG		76.7		77-5		76.4		77-2		77-6		77.3	
GENERATOR													
REACTIVE POWER	KVAR	1600		1705		1705		1580		1545		1365	
POWER FACTOR		-.93		-.92		-.91		-.91		-.91		-.92	
FREQUENCY	Hz	50		50		50		50		50		50	
VOLTAGE	V	11191		11368		11410		11421		11421		11421	
CURRENT	A	220		218		202		188		186		174	
VIBRATION													
GP B 3	um	13.5		13.8		12-1		13-6		13.1		13.5	
GP B 2	um	6.2		6.7		6.5		6-2		6-7		7-1	
GP B 1	um	30.4		31-3		31-8		30.5		30-5		30.7	
PANEL OPERATOR			MUHAIMIN			JASNI			FAIRUS			FAKHRUL	

ELECTRICITY

Parameters	Unit	0800	1000	1200	1400	1600	1800	2000	2200	2400	0200	0400	0600
GTU 0600 A	KW	3867	3954	3936	4040	3949	3993	3950	3846	3653	3379	3420	2843
GTU 0600 B		0	0	0	0	0	0	0	0	0	0	0	0
PRODUCTION		3867	3954	3936	4040	3949	3993	3950	3846	3653	3379	3420	2843
SUPPLY TO UTP		4405	4856	5011	5106	5311	4122	3612	3502	2495	2230	2272	2130
INPLANT USE		810	804	816	807	736	1865	1738	1427	1158	1149	1148	713
IMPORT FROM TNB		1336	1688	1891	1885	2138	1994	1400	1083	0	0	0	0

PLANT CONSUMPTION & MAJOR EQUIPMENT STATUS

NER reading (PARALLEL)
date 21/01/09 (Wednesday)
status GTG A & KO6

time	outside temp °C	NER temp.°C	NER Amp		GTG A load (KW)	mode
			from Gen.	to earth		
900	29.1	61	12.4	12.4	3937	parallel
1100	31.2	68.6	12.4	12.4	3928	parallel
1300	34.9	71.6	11.7	11.7	3842	parallel
1500	35	71.8	11.7	11.7	3862	parallel
1700	34.5	70.6	11.7	11.7	3881	parallel
1900	31.4	57.6	12.3	12.3	3855	parallel
2100						

nameplate;

line to Neut. Voltage	6.35 V
Initial current	200 Amps
Resistance	31.75 ohm @25°C
Time	10 secs
Phases	1
Frequency	50Hz
Type	GRID
BIL of Line kV	60

NER reading
date 30/01/09 (friday)
status GTG A & GTG B (ISLAND MODE)

time	outside temp	NER temp.		NER Amp				GTG LOAD	
		GTG A	GTG B	GTG A		GTG B		GTG A	GTG B
				from Gen.	to earth	from Gen.	to earth		
900	28.2	33	32.4	4.9	4.9	3.4	3.5	3358	2850
1100									
1300	33.8	45.4	45.6	4.3	4.3	4.8	4.6	3531	3276
1500	34.9	44.4	45.6	3.8	3.8	5.2	5.2	3599	3527
1700	35	43.2	42.6	4	4	4	4	3536	3405
1900	26.7	27.8	27.6	3	3	3	3	2527	2589
2100	27.5	26.8	27.8	3	3	3	3	2528	2495
2300	25.7	25.2	27.8	2	2	5	5	1407	2572

ELECTRICITY

Parameters	Unit	0800	1000	1200	1400	1600	1800	2000	2200	2400	0200	0400	0600
TU 6600 A	KW	3355	3370	3365	3537	3530	2832	2530	2521	0	0	0	6
TU 6600 B		2949	2844	3163	3432	3622	3021	2612	2580	3599	2817	2527	2606
RODUCTION		6304	6214	6528	6969	7152	5853	5112	5106	3599	2817	2527	2606
UPPLY TO UTP		4927	4807	5064	5114	5251	4294	3833	3828	2568	2253	2095	2158
NPLANT USE		1477	1407	1464	1855	1901	1559	1265	1267	981	554	460	446
MPORT FROM TNB		0	0	0	0	0	0	0	0	0	0	0	0

PLANT CONSUMPTION & MAJOR EQUIPMENT STATUS

A&I Management & Engineering Services (M) Sdn. Bhd.

Multilin SR489 Protection Relay Test Result

Job No : 0080/2007-40
Client : Makhostia Sdn. Bhd.
Installation : 11kV GTG-A Switchboard Panel, GDC UTP Tronoh.
Circuit : K02-CB-TG-1

Relay Details:

Make	:	GE	Aux. Volt	:	110Vdc
Type	:	Multilin SR489	VT Ratio	:	11kV/110V
Serial No.	:	A3210863	VT Connection	:	wye
Ground CT	:	100/5A	CT Ratio	:	500/5A.

Relay Setting:

Description	Service Setting
Overcurrent Alarm Alarm Delays Assign Alarm Relay	1.01 FLA 0.10s R5
Phase Overcurrent Enable Volt. Restraint Volt. Lower Limit Curve: ANSI Ext In Assign Trip Relay	Is: 3.60 CT Yes 10% TMS: 0.80 R1 & R3
N.S O/C Alarm Alarm Delays Assign Alarm Relay	10% FLA 5.0s R5
N.S O/C Trip Constant K Assign Trip Relay	20% FLA 40 R1 & R3
Ground O/C Alarm Alarm Delays Assign Alarm	0.80 CT 2.0 Cycle R5
Ground O/C Trip Curve: ANSI E.I Assign Trip Relay	1.50 CT 1.00 R1& R3
Phase Diff. Trip Diff. Trip Slope 1 Diff. Trip Slope 2 Diff. Trip Delay Assign Trip Relay	0.20 CT 10% 20% 100 cycles R1 & R4
High-Set Phase O/C Delay	3.80 CT 0.50s
Under Voltage Alarm Alarm Delays Assign Alarm	0.90 Un 3.0s R5
Under Voltage Trip Curve element: Curve Assign Trip Relay	0.80 Un 0.30s R1 & R3
Over Voltage Alarm Alarm Delays Assign Alarm Relay	1.10 Un 3.0s R5

Description	Service Setting
Over Voltage Trip Curve element: Curve Assign Trip Relay	1.20 Un 0.30s R1 & R3
Under Freq. Alarm Alarm Delays Assign Alarm Relay	49.0Hz 5.0s R5
Under Freq. Trip 1 Trip Delays Assign Trip Relay	49.0Hz 40.0s R1
Under Freq. Trip 2 Trip Delays Assign Trip Relay	47.5Hz 3.0s R1
Over Freq. Alarm Alarm Delays Assign Alarm Relay	51.0Hz 5.0s R5
Over Freq. Trip 1 Trip Delays Assign Trip Relay	51.0Hz 50.0s R1
Over Freq. Trip 2 Trip Delays Assign Trip Relay	52.5Hz 3.0s R1
Loss of Excitation: Enable Volt. Supervision Volt. Level Circle 1 Diameter Circle 1 Offset Circle 1 Trip Delay Assign Trip Relay	 Yes 0.80 Un 39.1Ω 2.4 Ω 3.0s R1
Reverse Power alarm Alarm Delay Assign Alarm Relay	0.05 x MW 10.0s R5
Reverse Power alarm Alarm Delay Assign Alarm Relay	0.05 x MW 10.0s R5
Reverse Power Trip Trip Delay Assign Trip Relay	0.05 x MW 20.0s R1 & R3

Test Results

1.0 Overcurrent Check. (RYB): Test setting = 0.50 CT

Description	Pickup Current (A)
RYB O/C	2.51

1.1 Timing Test (RYB).

Current Injected (A)	Voltage Injected (V)	Operating Time (s)
3.25	110	5.28
5.00	110	1.36
3.25	0.0	0.25
5.00	0.0	0.12

2.0 Negative Phase Sequence Check.

Description	Pickup Current (A)
RYB NPS	0.99

2.1 Timing Test (RYB).

Current Injected (A)	Operating Time (s)
1.80	5.023-alarm
5.00	156.259-Trip

3.0 Ground Overcurrent Check.

Description	Pickup Current (A)
Ground O/C Alarm	4.03
Ground O/C Trip	7.53

3.1 Timing Test

Current Injected (A)	Operating Time (s)
8	14.011
102	6.005
12	3.290

4.0 Phase Differential Trip Check.

Description	Pickup Current (A)		
	R-Phase	Y-Phase	B-Phase
Generator Line	1.03	1.01	1.03
Generator Neutral	1.01	1.01	1.02

5.0 High Set Phase Overcurrent Check: Test setting = 0.50 CT

Current Injected (A)	Operating Time (s)
3.25	0.514
5.00	0.520

6.0 Under Voltage Check (RYB).

Description	Alarm Pickup (V)	Trip Pickup (V)
Under Volt	98.99	86.42

6.1 Timing Test.

Volt Injected (V)	Operating Time (s)
98	3.040s- alarm
83	5.222-trip

VQ

Job No : 0080/2007-40

7.0 Over Voltage Check. (RYB).

Description	Alarm Pickup (V)	Trip Pickup (V)
Over Volt	121.05	134.23

7.1 Timing Test.

Volt Injected (V)	Operating Time (s)
125	3.045s- alarm
140	5.189-trip

8.0 Under Frequency Check. (RYB).

Description	Alarm Pickup (Hz)	Trip 1 Pickup (Hz)	Trip 2 Pickup (Hz)
Under Freq.	49.0	49.0	47.5
Operating Time (s)	4.959	39.295	2.967

9.0 Over Frequency Check. (RYB).

Description	**Alarm Pickup (Hz)**	**Trip 1 Pickup (Hz)**	**Trip 2 Pickup (Hz)**
Over Freq.	51.0	51.0	52.5
Operating Time (s)	5.210	51.117	3.302

10.0 Loss of Excitation Check.

Reach Tested	**Current Injected (A)**	**Operating Voltage (V)**	**Reach Measured (Ω)**	**Operating Time (s)**
Diameter 1	1.0	40.90/ 90°	40.90	3.066
Offset 1	1.0	4.18/ 90°	4.18	

11.0 Reverse Power Check. (RYB).

Description	**Volt Injected(V)**	**Pickup Current (A)**
Reverse Power	110.0	0.14

11.1 Timing Test (RYB).

Voltage Injected (V)	**Current Injected (A)**	**Operating Time (s)**
110.0	0.15	10.011-alarm
110.0	0.15	20.042-trip

11.2 Boundary Check

Voltage Injected (V)	**Current Injected (A)**	**Operating Angle(°)**	
110	1.00	-99°	+263°

Tripping Contact : Ok
Remarks : Maintenance test.
Tested by : K.S Wong
Date : 14/04/2007

Certified by,

JURUTERA PERKHIDMATAN ELEKTRIK
IR. ISMAIL OMAR
JP-T-2-B
0062-1996
SURUHANJAYA TENAGA

NER VALUE

MODE	DATE	TIME	NER CURRENT (AMP)		LOAD (KW)		MODE	OPERATE		
			GTG A	GTG B	GTG A	GTG B		GTG A	GTG B	TNB
1	6/20/2009	1300	7.7	-	3504	-	ISLAND			
2	1/30/2009	1300	4.3	4.8	3531	3276	ISLAND			
3	6/19/2009	1700	11.6	-	3625	-	PARALLEL			
4	7/14/2009	2045	7.0	8.8			PARALLEL			
1	6/22/2009	2300	-	9.2	-	3396	ISLAND			
2	6/24/2009	1300	3.5	5.8	3648	3399	ISLAND			
3	6/25/2009	700	-	16	-	1974	PARALLEL			
4	6/26/2009	1100	7.4	19.2	3212	2934	PARALLEL			

											■	ON		N=	31.75 Ω	
											■	OFF		L=	10.58 Ω	

NER Current Measurement

DATE	TIME	OUTSIDE TEMP(°C)	NER TEMP(°C)		NER AMPS		LOAD (KW)		MODE	OPERATE			NER		MODE
			GTG A	GTG B	GTG A	GTG B	GTG A	GTG B		GTG A	GTG B	TNB	GTG A	GTG B	
21/01/2009	900	29.1	61	-	12.4		3937	-	PARALLEL				N	N	3
	1100	31.2	68.6	-	12.4		3928	-	PARALLEL				N	N	3
	1300	34.9	71.6	-	11.7		3842	-	PARALLEL				N	N	3
	1500	35.0	71.8	-	11.7		3862	-	PARALLEL				N	N	3
	1700	34.5	70.6	-	11.7		3881	-	PARALLEL				N	N	3
	1900	31.4	57.6	-	12.3		3855	-	PARALLEL				N	N	3
30/01/2009	900	28.2	33	32.4	4.9	3.4	3358	2850	ISLAND				N	N	2
	1300	33.8	45.4	45.6	4.3	4.8	3531	3276	ISLAND				N	N	2
	1500	34.9	44.4	45.6	3.8	5.2	3599	3527	ISLAND				N	N	2
	1700	35.0	43.2	42.6	4	4	3536	3405	ISLAND				N	N	2
	1900	26.7	27.8	27.6	3	3	2527	2589	ISLAND				N	N	2
	2100	27.5	26.8	27.8	3	3	2528	2495	ISLAND				N	N	2
	2300	25.7	25.2	27.8	2	5	1407	2572	ISLAND				N	N	2
19/06/2009	1500	36.6	70	-	11.4	-	3726	-	PARALLEL				N	N	3
	1700	35.3	65	-	11.6	-	3625	-	PARALLEL				N	N	3
	1900	31.3	64	-	11.6	-	3777	-	PARALLEL				N	N	3
	2100	30.2	65	-	11.6	-	3634	-	PARALLEL				N	N	3
	2300	29.7	47	-	7.3	-	3428	-	ISLAND				N	N	1
20/06/2009	900	30.8	45	-	7.1	-	2922	-	ISLAND				N	N	1
	1100	33.3	52.8	-	7.6	-	3518	-	ISLAND				N	N	1
	1300	36.8	52.4	-	7.7	-	3504	-	ISLAND				N	N	1

	1500	38.5	60	-	7.3	-	3296	-	ISLAND				N	N	1
	1700	35.6	53	-	7.1	-	3280	-	ISLAND				N	N	1
	1900	30	41	-	6.9	-	3243	-	ISLAND				N	N	1
	2100	25	41	-	7.2	-	3366	-	ISLAND				N	N	1
	2300	25	41	-	7	-	3257	-	ISLAND				N	N	1
21/06/2009	900	32.1	48.6	-	5.8	-	2588	-	ISLAND				N	N	1
	1100	34.9	54	-	7.2	-	3559	-	ISLAND				N	N	1
	1300	36.7	56	-	6.9	-	3407	-	ISLAND				N	N	1
	1500	33.3	-	42	-	0.9	-	3452	ISLAND				N	L	1
	1700	33.6	-	42	-	0.91	-	3404	ISLAND				N	L	1
	1900	30.7	-	38	-	0.9	-	3309	ISLAND				N	L	1
	2100	27.9	-	37	-	0.9	-	3542	ISLAND				N	L	1
22/06/2009	900	30.2	35	37	3.4	5.5	3343	3084	ISLAND				N	L	2
	1100	33.1	45	45	1.9	7.3	3380	3382	ISLAND				N	L	2
	1300	36	49	51	1.7	7.6	3392	3538	ISLAND				N	L	2
	1500	35	41	44	1.8	7.8	3350	3622	ISLAND				N	L	2
	1700	28	33	31	2.9	5.1	2935	2716	ISLAND				N	L	2
	1900	27	28	27	4.1	2.9	2761	1947	ISLAND				N	L	2
	2100	24	26	27	1.9	5.3	2016	2524	ISLAND				N	L	2
	2300	23	-	25	-	9.2	-	3396	ISLAND				N	L	1
23/06/2009	900	31	37	37	3.2	5.2	3345	2946	ISLAND				N	L	2
	1100	33	46	46	2.8	6.1	3269	3214	ISLAND				N	L	2
	1300	36	46	48	2.2	7.2	3280	3488	ISLAND				N	L	2
	1500	36	49	50	1.9	7.8	3314	3516	ISLAND				N	L	2
	1700	34	40	38	3.6	4.3	3283	2400	ISLAND				N	L	2
	1900	27	29	29	2.6	4.6	2880	2331	ISLAND				N	L	2
	2100	27	27	30	1.8	6.6	2302	3008	ISLAND				N	L	2

	2300	26	-	31	-	9.3	-	3498	ISLAND				N	L	1
24/06/2009	900	28	29	34	2.5	6.1	3486	3036	ISLAND				N	L	2
	1100	38	40	43	1.2	8.3	3477	3492	ISLAND				N	L	2
	1300	34	42	44	3.5	5.8	3648	3399	ISLAND				N	L	2
	1500	41	51	50	3.1	6.3	3628	3382	ISLAND				N	L	2
	1700	28	30	31	2.3	5.6	2819	2772	ISLAND				N	L	2
	1900	28	27	27	1.8	5.8	2526	2700	ISLAND				N	L	2
	2100	27	26	27	2	5.6	2528	2600	ISLAND				N	L	2
	2300	26.5	-	42	-	19.6	-	2931	PARALLEL				N	L	3
25/06/2009	200	24	-	53	-	17.9	-	2449	PARALLEL				N	L	3
	700	24	-	53	-	16	-	1974	PARALLEL				N	L	3
	800	28.2	39.8	53.1	7.5	19.9	3206	3033	PARALLEL				N	L	4
	900	30	51.6	65.6	7.3	18.1	3135	2960	PARALLEL				N	L	4
	1100	32.8	50.1	65.4	7.4	19.2	3212	2934	PARALLEL				N	L	4
	1300	35.3	59	70.6	7.2	18	2986	2889	PARALLEL				N	L	4
	1500	36.6	51.4	68.6	6.4	20	3078	3301	PARALLEL				N	L	4
14/07/2009	1845	35.4	41.6	42.4	6.9	7.8			PARALLEL				N	N	4
	1945	32	41.2	44.2	7.6	8.3			PARALLEL				N	N	4
	2045	28.8	41.2	45.6	7.0	8.8			PARALLEL				N	N	4
	2145	25.4	39.6	46.8	7.2	8.4			PARALLEL				N	N	4
	2245	26.4	37.4	43	6.6	7.6			PARALLEL				N	N	4

GANTT CHART

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NO	DETAIL / WEEK	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
1	GDC Measurement														
13	Data gathering														
14	Data Analysis														
15	Solution proposal														
16	GDC presentation														
17	Final Presentation														